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Marie Lassalas

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IMPACTS OF ENVIRONMENTAL STANDARDS ON FARMS

Thèse de doctorat de l'institut national d'enseignement supérieur pour l'agriculture,
l'alimentation et l'environnement, école interne l'Institut Agro Rennes-Angers

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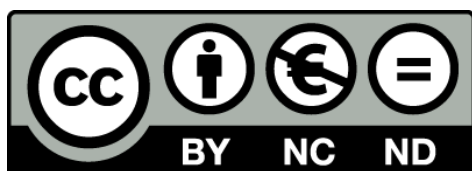
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List of abbreviations

2SLS	Two-Stage Least Squares
AECMs	Agri-Environment-Climate Measures
AEMs	Agri-Environmental Measures
AES	Agri-Environmental Schemes
AIC	Akaike Information Criterion
AL	Arable Land
ATT	Average Treatment effect on the Treated
BFE	Biodiversity Friendly Elements
CAP	Common Agricultural Policy
COP	Cereals, Oilseeds and Protein crops
DCE	Discrete Choice Experiment
ESR	Endogenous Switching Regression
EU	European Union
FADN	Farm Accountancy Data Network
GA	Green Architecture
GAEC	Good Agricultural and Environmental Conditions
GHGs	Greenhouse Gases
GI	Geographical Indications
GSP	Gross Standard Production
HEV	High Environmental Value
IPBES	Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services
IPCC	Intergovernmental Panel on Climate Change
MSs	Member States
MXL	Mixed Logit
NAA	Non-Attendance Attribute
NSP	National Strategic Plan
NVA	Nitrate Vulnerable Areas
PDO	Protected Designation of Origin
PG	Permanent Grasslands
SC	Scale Change
SF	Stochastic Frontier
SQ	Status Quo
SUTVA	Stable Unit Treatment Value Assumption
TC	Technical Change
TE	Technical Efficiency
TEC	Technical Efficiency Change
TFI	Treatment Frequency Index
TFP	Total Factor Productivity
TFPC	Total Factor Productivity Change
TGR	Technology Gap Ratio
TT	Treatment effects on the Treated
UAA	Utilized Agricultural Area

Chapter 1. General introduction

*Agriculture has strong impacts on both climate change and biodiversity loss. The intensification of agricultural practices is a major driver of climate change and biodiversity loss. Worldwide, the agricultural sector accounted for 23% of the total net anthropogenic greenhouse gases (GHGs) from 2007 to 2016 (IPCC, 2019). It was responsible for 13% of carbon dioxide (CO₂), 44% of methane (CH₄), and 81% of nitrous oxide (N₂O) emissions from human activities (IPCC, 2019). Methane emissions result principally from livestock enteric fermentation and manure management. Nitrous oxide emissions come mainly from the application of mineral and organic nitrogen fertilizers to the soil. Carbon dioxide largely results from liming and the application of urea. Last, agriculture also plays a significant role in driving greenhouse gas emissions through land use change. The report of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) notes that extinction threatens approximately one million species (IPBES, 2019) and that agriculture and the overexploitation of wild species are the main drivers of biodiversity decline (Maxwell *et al.*, 2016; Tilman *et al.*, 2017; IPBES, 2019). The intensification of agricultural practices harms biodiversity through various channels: habitat destruction and homogenization through the spreading of monoculture and removing of hedgerows, the use of chemical inputs (pesticides and fertilizers) and tillage (Benton *et al.*, 2003; Hautier *et al.*, 2009; Geiger *et al.*, 2010; Beketov *et al.*, 2013; Arslan, 2018; Sánchez-Bayo and Wyckhuys, 2019; Raven and Wagner, 2021). The adverse effects of agriculture on water and soil compartments are also concerning. In 2012, 43% of European surface waters exhibited intermediate or low-quality conditions because of high nitrate concentrations (European Commission, 2018). Moreover, agriculture places stress on this resource due to irrigation. It accounted for 51% of the total water use in the European Union (EU) in 2014 (European Commission, 2018). Additionally, it is worth noting that erosion affects 13% of arable land in the EU and that soils are damaged due to compaction (European Commission, 2018).*

Policy-makers have become aware of and have addressed environmental issues for many years, although the successive commitments they have made have only been partially fulfilled, as highlighted by the European Environment Agency (2019). At the EU level, the Green Deal is the latest European policy setting for environmental objectives. The environmental targets related to agriculture are consolidated within the Farm-to-Fork Strategy. The main objectives set for 2030 are as follows: (1) a 50% reduction in pesticide use, (2) 20% a decrease in fertilizer use and (3) a conversion of 25% of the agricultural land under organic farming (European

Commission, 2020). The Farm-to-Fork Strategy report claims that the European Common Agricultural Policy (CAP) must sustain the transition. Regarding environmental issues, the public nature of the good and/or externalities that arise justifies policy intervention.

The CAP has introduced several instruments aimed at incentivizing farmers to embrace environmentally friendly practices. One of the initial instruments, known as Agri-Environmental Measures (AEMs), was extended to all Member States in 1992. In 2013, they were renamed Agri-Environment-Climate Measures (AECMs) to encompass the climate dimension. AECMs are voluntary 5-year contracts, providing farmers with subsidies from the CAP's second pillar to offset the additional costs or income reductions associated with the adoption of environmental practices. In 2003, a mandatory instrument, known as conditionality, was introduced. To receive income support direct payments from the CAP's first pillar, farmers must comply with regulations on environmental protection, human health, animal health, and plant health, as well as meet Good Agricultural and Environmental Conditions (GAEC). In 2013, the CAP reform introduced greening, which linked 30% of direct payments from the first pillar to three criteria: crop diversification, maintaining permanent grasslands, and preserving agro-ecological infrastructures. While the voluntary or mandatory nature of this instrument can be debated, the European Commission presents it as mandatory, with financial sanctions for noncompliance. Starting in 2023, greening measures have been integrated into enhanced conditionality within the Green architecture of the 2023-2027 CAP. Additionally, a new instrument, the eco-scheme, emerges within this programming period. This voluntary instrument aims to reward farmers who are already implementing environmentally friendly practices and encourage others to adopt them. It represents 25% of the first pillar CAP budget. Consequently, farmers who do not adjust their practices to access subsidies from this instrument will face significant reductions in their first pillar subsidies. Each Member State is responsible for defining its own eco-scheme within its National Strategic Plan (NSP). Runge *et al.* (2022) highlight the considerable diversity in choices made by Member States.

Despite the introduction of mandatory and voluntary environmental instruments, successive reforms of the CAP have failed to date to improve the environmental sustainability of European agriculture (Navarro and López-Bao, 2018; Pe'Er *et al.*, 2019). Numerous criticisms are directed toward the instruments of agri-environmental policy within the CAP and their implementation. Conditionality has been criticized for its lack of ambition in terms of environmental constraints and its weak sanctions (European Court of Auditors, 2020). Its efficiency is questioned in light of the allocated budget, as the subsidies of the first pillar

received by farmers are determined by the characteristics of the farms rather than the actual practices implemented (Meyer *et al.*, 2014). The greening payment was intended to be more ambitious in terms of environmental constraints. However, the requirements of greening are minimally restrictive for farmers and align more with customary agricultural practices (European Court of Auditors, 2020). According to the European Court of Auditors (2017), the greening payment only introduced ecological elements on approximately 3.5% of the EU's arable land and induced a change in agricultural practices on permanent grassland on merely 1.5% of the agricultural land in the EU. The effectiveness of AECM is also challenged on several fronts. First, the voluntary adoption rate of AECM is insufficient to enhance the state of the environment due to unattained thresholds necessary for providing certain environmental benefits (Zavalloni *et al.*, 2019a). As an example, a single farmer changing practices is not enough to improve the water quality of an aquifer. Achieving an improvement in water quality necessitates the commitment of a significant number of farmers. In addition, the lack of spatial continuity in the implementation of environmental practices restricts their actual impact on the environment (Westerink *et al.*, 2015; Westerink *et al.*, 2017). For instance, ensuring the survival of a species relies on restoring the continuity of its habitat. AECMs frequently faces criticisms for being based on the implementation of practices rather than the achievement of tangible environmental outcomes (Herzon *et al.*, 2018). Moreover, Chabé-Ferret and Subervie (2013) reveal the significant presence of opportunistic behavior associated with many AECMs. Many farmers were already implementing the practices before contracting AECMs. This partly explains why the least demanding AECMs have the highest adoption rates.

Instruments promoting coordination among farmers offer a solution to tackle some of the shortcomings of AECMs. To improve AECMs adoption rates, one can incentivize coordination among farmers with a collective bonus. The collective bonus is an extra payment given to all farms participating in the AECM when a minimum participation threshold is achieved. This threshold can be linked to the number of hectares or the number of farms enrolled in the AECM (Kuhfuss *et al.*, 2019; Zavalloni *et al.*, 2019b). To encourage spatial continuity, an agglomeration bonus is an option. All farms participating in the AECM receive this bonus if their neighboring farmers also participate in the AECM (Banerjee *et al.*, 2014; Kuhfuss *et al.*, 2019). Contracting AECM collectively with a group of farmers fosters stronger coordination among them (Westerink *et al.*, 2017). In collective AECMs, the evaluation of requirements occurs at the collective level, and the payment is distributed among farmers according to the rules established by the collective. The Netherlands first introduced collective contracting

between the Dutch government and environmental cooperatives in 1992 (Wiskerke *et al.*, 2003; Franks, 2011). Since 2014, the EU has made collective contracting possible within the framework of AECMs. However, examples in other European countries are scarce. In France, there is only one collective AECM, which aims to preserve European Hamster habitats (Osswald, 2019). It is also the only AECM for which the payment received by farmers depends on the contractualization rate, similar to collective bonuses.

To complement agri-environmental policies, supply chains may play a role in promoting farmers' adoption of environmental practices to both increase the adoption rate of environmental practices and ensure spatial continuity in their implementation. Stakeholders within supply chains have a privileged relationship with farmers, upstream by supplying inputs and downstream by managing farm production sales. Several empirical studies highlighted the positive effect of agricultural cooperatives in incentivizing farmers to adopt environmentally friendly practices (Candemir *et al.*, 2021).

The agri-food supply chain may resort to contracting to encourage farmers to adopt environmental practices (Magrini *et al.*, 2023). Contracting is a tool for vertical coordination among stakeholders in the supply chain (Bouamra-Mechemache *et al.*, 2015). They are levers for improving supply chain performance and, in particular, for encouraging quality and innovation. Contracts also prove to be valuable tools for managing market risks (price and market outlets) and production risks (related to climatic or health events) by facilitating fair risk sharing among supply chain stakeholders (Bouamra-Mechemache *et al.*, 2015). Contracts can take various forms. Goodhue (2011) distinguishes three types of contracts: marketing contracts, production-management contracts, and resource-providing contracts. Marketing contracts outline the conditions of sale, such as the pricing structure and the quantity to be sold. They may also specify the expected quality or include quality incentives within the price formula. Under marketing contracts, a farmer maintains ownership of the output until the sale, and he or she is responsible for all production decisions before then. Production-management contracts encompass certain elements of the production process and outline the farmer's compensation. In these contracts, the buyer is involved in specific management decisions, while the farmer maintains ownership of the output until delivery. Resource-providing contracts can refer to vertical integration. The buyer provides to the farmer some production inputs and participates in management decisions. The buyer retains ownership of the crop or animal throughout the production process. Thus, supply chain stakeholders can specify environmental practices that

farmers must implement or prohibit the use of certain inputs in production-management contracts and resource-providing contracts. They can also incentivize farmers to adopt these environmental practices through monetary incentives within marketing contracts. Additionally, contracts, as a coordination tool within supply chains, increase both formal and informal exchanges among stakeholders, which can support the adoption of environmental practices (Magrini *et al.*, 2023). Contracts are commonly complemented by technical advisory services provided to farmers (Duvaleix *et al.*, 2020). Counseling and training are indeed key drivers for promoting the adoption of new practices and technologies at the farm level (Naziri *et al.*, 2014; Wossen *et al.*, 2017; Yu and Huang, 2020).

However, the implementation of environmental practices by farmers during production is a credence attribute that cannot be verified at the time of purchase. One of the levers is therefore to link the monetary incentives of the marketing contract to environmental standards certified by a third-party organization. We adopt the definition of standard proposed by Rousset *et al.* (2015): “sets of rules, guidelines or characteristics for product or related process and production methods with which compliance is not legally mandated and, hence, voluntary”. Environmental standards aim to reduce information asymmetry between farmers and buyers (business-to-business standards) and between farmers and consumers (business-to-consumer standards). In the latter case, information is disclosed to consumers through a label on the product. The environmental label allows for vertical differentiation and enables the product to be marketed with a price premium (Bonroy and Constantatos, 2015; Asioli *et al.*, 2017). The development of environmental standards is growing worldwide. The Ecolabel Index (2021) reported 455 environmental labels in 199 countries and 25 industry sectors. In the agricultural sector, public and private organizations have developed numerous environmental labels to respond to consumers’ increasing interest. In a 2014 survey conducted by the European Commission, it was found that 75% of Europeans expressed a willingness to purchase environmentally friendly products, even if they came at a slightly higher cost (European Commission, 2014). Sessego and Hébel (2019) found that in 2018, 70% of French people had bought at least one organic product in the previous six months, whereas in 1998, only 44% of them had done so.

Due to their establishment within well-defined territories, supply chains can also play a role in ensuring spatial continuity in the adoption of practices if they can successfully engage a significant number of farmers within their region. This second aspect has received limited attention in the literature, and the presence of multiple stakeholders within the same territory can challenge its results. Geographical indications (GI) demonstrate an example of successful

spatial continuity in the adoption of practices. Some GI standards incorporate environmental practices in their requirements even if it is not their primary focus (Vandecandelaere *et al.*, 2009; Belletti *et al.*, 2015; Marescotti *et al.*, 2020).

To explain why supply chain stakeholders may voluntarily promote the adoption of environmental practices by farmers, we outline in Table 1.1 various channels that yield economic benefits for stakeholders within the supply chain. The first part of the table presents examples where the adoption of environmental practices are opportunities to increase revenues. The second part of the table illustrates how this adoption can be a way to reduce costs.

Table 1.1. Economic benefits for supply chain stakeholders from promoting the adoption of environmental practices on farms

Opportunity	Channel	Example in the agri-food supply chain
<i>Environmental practices as an opportunity to increase revenues</i>		
Better access to some markets (Ambec and Lanoie, 2008; Lanoie and Llerena, 2015)	Improves firms' reputation, avoid boycott campaigns (Hartmann and Moeller, 2014) Companies pay attention to suppliers' environmental performances to avoid having to bear supply chain environmental responsibility (Hartmann and Moeller, 2014) Public administration procurement policy may include environmental criteria for the choice of their suppliers (Ambec and Lanoie, 2008)	Nestlé withdraws palm oil, obtained through unsustainable behaviors by one of its supplier, from its products (Hartmann and Moeller, 2014) By 2022, French public institutions will have to provide collective catering with meals of which at least 50% of the value of the products are of high quality and sustainable, and of which at least 20% are organically grown (Article 24 of EGAlim law n° 2018-938)
Redefinition of the market in order to capture more value (Carpentier and Ervin, 2002)	Redesign of contracts with supply-chain downstream players	Tripartite contracts developed within the pork industry between farmers, slaughterhouses and retailers such as 'La Nouvelle Agriculture' (Lassalas <i>et al.</i> , 2020)
Competitive advantage (Carpentier and Ervin, 2002, Lanoie and Llerena, 2015)	In the case competitors are forced to increase their production costs to stay competitive	
Product differentiation (Ambec and Lanoie, 2008, Lanoie and Llerena, 2015)	Environmental label	Organic label
Anticipation of future environmental regulations (Carpentier and Ervin, 2002)		Development of environmental cooperatives in the Netherlands (Wiskerke <i>et al.</i> , 2003)
Sale of new technologies to mitigate pollution (Ambec and Lanoie, 2008, Lanoie and Llerena, 2015)		Sale of extruded flax by Valorex, incorporating flax into cows' diet reduce enteric methane emissions (Cholez, 2019; Le Gloux <i>et al.</i> , 2023)

Continued

Table 1.1 (continued)

Opportunity	Channel	Example in the agri-food supply chain
<i>Environmental practices as an opportunity to decrease costs</i>		
Rise in productivity resulting from better management of natural resources (Porter hypothesis) (Ambec and Lanoie, 2008, Porter and Linde, 1995)	Decrease in input consumption and better waste management (Lanoie and Llerena, 2015)	Improved nitrogen use efficiency would lead to an increase in the quantity of goods produced and a reduction in nitrogen discharges (Piot-Lepetit <i>et al.</i> , 2002) Reuse of excrements for energy (Lanoie and Llerena, 2015)
Risk management and relations with external stakeholders (Ambec and Lanoie, 2008)		In the event of an environmental accident, the costs from prosecutions and fines can be reduced (Lankoski, 2006) Obtain more easily from the government and society the support for expansion or building new infrastructures (Ambec and Lanoie, 2008)
Capital cost reduction (Ambec and Lanoie, 2008, Lanoie and Llerena, 2015)	Have easier access to loans from banks Use of green mutual funds	
Labor cost reduction (Ambec and Lanoie, 2008, Lanoie and Llerena, 2015)	Motivated employees who will be more productive and less ill Easier recruitment of young talent	
Secure its supplies (Delmas <i>et al.</i> , 2019)		Unilever developed the Marine Stewardship Council label in partnership with the NGO WWF to guarantee the long-term supply of fish whose inventories are decreasing (Wijen and Chiroleu-Assouline, 2019)

Governments make use of agri-food standards to achieve policy objectives. Initially, supply chains developed environmental standards as a means of product differentiation on the market for food produced under specific requirements regarding the implementation of environmental practices by farmers. Later, governments also chose to use standards in their policy mix. Rousset *et al.* (2015) highlight two primary reasons why a government chooses to use standards. The first is that the government intends to improve the functioning of the food market to protect consumers from false or misleading claims. The second is that the government aims to achieve other public objectives by incorporating standards into their policy mix. In the following analysis, we discuss the utilization of environmental standards by the French government and the EU to promote the adoption of environmental practices by farmers.

The first standards in the agri-food sector designed to fulfill a policy objective were GI. The French government established them in the early 20th century as a measure to combat fraud. A decree law was introduced in 1935 for wines and spirits, and then in 1990, it was extended to encompass all agri-food products. GI standards certify that the production and processing of relevant products occur in a defined geographical area and following specific requirements. This policy, based on the utilization of standards, was subsequently expanded to the EU in 1992, initially for wines and spirits, and later in 2009 for all agri-food products.

Regarding environmental standards, French policy officially recognized the organic standard in 1981 based on private specifications introduced since 1972. Later, in 1992, the requirements were harmonized at the European level. Beyond recognizing the organic standard, the French government also supports both the supply and demand for certified organic agri-food products. Support for supply primarily took the form of subsidies for conversion and maintenance, granted under the CAP, as well as through tax credits. Support for demand has taken various forms, such as the EGALIM law. Article 24 of the EGALIM law (n° 2018-938) specifies that by 2022, French public institutions will be required to offer collective catering services with meals in which at least 50% of the product value consists of high-quality and sustainable products, of which at least 20% are organically produced.

To further promote its environmental policy within the agricultural sector, in 2007, during the *Grenelle de l'environnement*, the French government initiated discussions with stakeholders around an environmental standard. It led in 2012 to the publication of the requirements specification of the standard. The environmental certification system offers three levels of certification, with only the third level permitting the use of a label on products. This corresponds to the High Environmental Value (HEV) standard. The increased support provided by the

French government for the development of this standard contributed to its growth. As of 2023, nearly 10% of French farms hold this certification (Ministère de l'agriculture et de la souveraineté alimentaire, 2023). Similar to organic farming, the government bolstered demand for the HEV standard through the EGALIM law, as the HEV standard falls under the category of sustainable products. Support for supply was provided through tax credits, regional subsidies, and funding from water agencies. Furthermore, following the 2023 CAP reform, the HEV and the organic standard grant access to eco-scheme subsidies.

Several indications suggest that both the French government and the European Union intend to continue utilizing environmental standards to support their environmental policies within the agricultural sector. Indeed, the European Commission declares in the Farm to Fork Strategy that it aims to create a sustainable standard and to harmonize voluntary green initiatives (European Commission, 2020). Furthermore, the French government is currently working on the eco-score, which is an environmental impact label aiming to communicate actual impacts rather than adherence to a set of practices, as environmental standards do (Hélias *et al.*, 2022).

We identify several interventions that the government and the European Commission have implemented or intend to implement: supporting the public recognition of initially private standards, encouraging the harmonization of existing standards, developing public standards, stimulating the growth of standards, and building regulations on existing standards. Standards can be viewed as a decentralized instrument to support the private production of environmental goods (Kotchen, 2006). Building regulations on existing standards or using standards as an option to comply with regulations can offer a dual benefit by reducing administrative costs and transaction costs (Rousset *et al.*, 2015).

My PhD thesis explores various environmental standards implemented and promoted by both supply chains and public policies. In the next section, I present the scope of the PhD thesis and the research questions that we seek to answer.

1.1. Scope of the PhD thesis and research questions

The general objective of this PhD thesis is to investigate whether environmental standards can be a tool for incentivizing the adoption of environmental practices by farmers. I will explore the use of environmental standards within both supply chains and the design of public policies.

Society and European governments have become increasingly aware of environmental issues regarding the agri-food sector. To address these challenges, they set ambitious goals, as outlined in the Green Deal (European Commission, 2020). However, the implemented agri-environmental policies have failed to date to improve the environmental sustainability of European agriculture (Navarro and López-Bao, 2018; Pe'Er *et al.*, 2019). Supply chains, due to their privileged relationship with farmers and contractual arrangements, play a role in promoting the adoption of environmental practices among farmers (Candemir *et al.*, 2021). Moreover, supply chain stakeholders establishment within specific territories has an opportunity to achieve spatial continuity in the adoption of environmental practices. This stands in contrast to agri-environmental policies, which are deficient in this regard and thus limit the environmental impact of these policies (Westerink *et al.*, 2015; Westerink *et al.*, 2017). Over the past two decades, supply chains have introduced numerous environmental standards in response to consumer demands for environmentally differentiated products (Ecolabel Index, 2021). Some consumers' willingness to pay a premium for products with environmental standards enables supply chain stakeholders to offer monetary incentives to farmers for the adoption of environmental practices and to cover the costs associated with their adoption. Subsequently, governments also adopted environmental standards to achieve agri-environmental policy objectives (Ministère de l'agriculture et de la souveraineté alimentaire, 2022). Figure 1.1 illustrates the interaction of environmental standards between supply chains and agri-environmental policies. Environmental standards can be both public and private, depending on the entity responsible for the requirements specification. The interactions between environmental standards and public policies are diverse, including public recognition of initially private standards, the harmonization of existing standards, the promotion of standards to increase supply and demand, and the development of regulations based on existing standards.

By focusing on the adoption of environmental standards as a means for farmers to adopt environmental practices, I choose to emphasize the adoption of a voluntary measure despite economic theory predicting that voluntary measures are suboptimal for providing public goods. Voluntary provision of public goods aligns with an individual's marginal utility, while socially

optimal provision corresponds to the sum of individual marginal utilities (Samuelson, 1954). This leads to challenges such as low adoption rates and self-selection in voluntary measures adoption. However, it appears important to explore this voluntary tool to incentivize the adoption of environmental practices because the number of environmental standards is growing worldwide and the European Union built agri-environmental policies on a mix of voluntary and mandatory instruments, as outlined in Figure 1.1. Although the adoption of standards is voluntary by definition, some can become implicitly mandatory because they are essential for farmers to enter the market (indicated by dashed lines in Figure 1.1). An illustration of this is the GlobalGAP standard, which was established by a consortium of European supermarket chains, with the aim of ensuring food safety by developing good agricultural practices that farmers must adopt (Tey *et al.*, 2016).

A literature gap also motivated the choice to study environmental standards as a tool to incentivize the adoption of environmental practices by farmers in this PhD thesis. Unlike agri-environmental policies, which have been extensively studied in the literature, as evidenced by the numerous studies on AECMs, few studies have focused on environmental standards, with the exception of the organic farming standard.

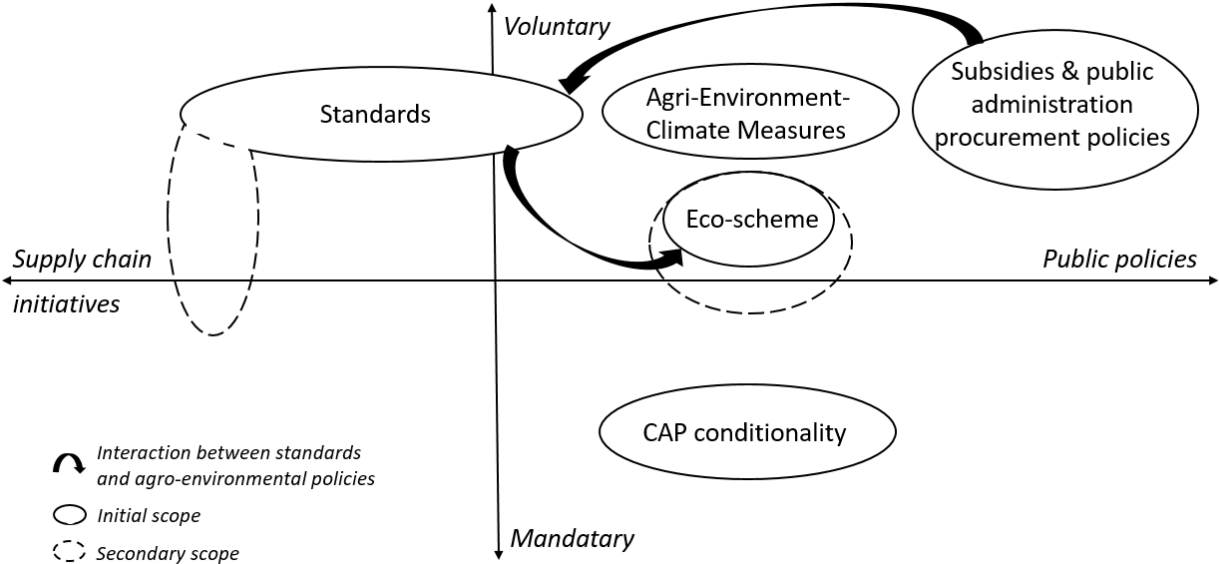


Figure 1.1: Standards within the supply chain and their interaction with agri-environmental policies

To address the general objective of this PhD thesis, which is to investigate whether environmental standards can be a tool to incentivize the adoption of environmental practices by farmers, I investigate three research questions. First, voluntary adoption of environmental practices can be facilitated if it comes with an improvement in farms' performance; thus, we aim to examine the following:

Research question 1: What are the effects of adopting environmental standards on the agronomic and economic performances of farms?

Second, voluntary adoption of environmental practices can be influenced by factors beyond purely economic interests. The literature review by Dessart *et al.* (2019) highlights various behavioral factors that affect the adoption of environmental practices. Exploring the avenues through which supply chains can support farmers through contractual arrangements is also interesting, not only for economic reasons but also in response to these behavioral factors. Therefore, our aim is to investigate the following:

Research question 2: What are the attributes of farming contracts that can foster the adoption of environmental standards?

Last, in recent years, public policies have increasingly included standards to achieve policy objectives. These voluntary measures appear to be complementary to mandatory measures. Hence, our objective is to analyze the following:

Research question 3: What is the impact of incorporating environmental standards into public policies on farmers' practices?

This PhD thesis focuses on environmental standards based on a set of practice requirements and not on impact reporting labels aiming to communicate actual product impacts. Evaluating the current impact of environmental standards on the environment is out of the scope of this PhD thesis. While consumer demand and willingness to pay for environmental standards are crucial to the development of environmental standards, it was beyond the scope of this PhD thesis, as was their implications for the global agri-food supply chain.

1.2. Outline of the PhD thesis

In this section, I outline how the chapters of this PhD thesis contribute to addressing the three research questions.

We address the first research question, dealing with the impact of environmental standards adoption on the agronomic and economic performances of farms, through two case studies within two chapters of the PhD thesis: Chapter 2 and Chapter 3. The two approaches differ in terms of the standards under study, the scale of the study, and the methodologies employed.

Chapter 2 focuses on the organic standard. Studying this standard is particularly relevant given that the EU has set a quantitative target of 25% of agricultural land to be converted to organic farming by 2030 (European Commission, 2020). However, the scope of the article extends beyond studying the impact of adopting organic practices on farms' performance. The paper was set up in light of the observation that the CAP requires meeting ambitious environmental objectives while ensuring food supply and farmers' income. We aim to assess how two established instruments, agri-environmental schemes (AES)¹ and organic subsidies, impact farms' productivity. These instruments are anticipated to feature CAP tools in the future to incentivize farmers to adopt environmental practices. From a public policy standpoint, we aim to ascertain whether government support for the voluntary adoption of environmental practices impacts the efficiency and productivity of the participating farms.

Our analysis focuses on crop farms in the Poitou-Charentes region of France during the 2014-2020 CAP program. To estimate farms' technical efficiency and productivity by their total factor productivity, we apply the stochastic metafrontier model developed by Huang *et al.* (2014). To analyze the effect of the adoption of AES and organic contracts, we calculate the average treatment effect on the treated using the difference-in-differences methodology.

This paper contributes to the literature aiming at evaluating the impact of the adoption of organic farming and AES on technical efficiency (Lakner and Breustedt, 2017; Baráth *et al.*, 2020; Mennig and Sauer, 2020; Dakpo *et al.*, 2022). The main contributions are twofold. Applying a metafrontier model allows us to compare the technical efficiency of AES and organic farms to conventional farms while taking into account different technologies for each

¹ In this chapter, we refer to AECM with the term AES, which encompasses a broader context beyond the measures specific to the CAP.

group. Unlike earlier studies on organic farming that typically compare a group of conventional farms with a group of organic farms, we focus on farms adopting organic farming within the study period. We investigate the changes in their efficiency before and after adoption.

Our findings indicate that the adoption of an AES contract has no impact on farms' efficiency, both in terms of their efficiency relative to their own production frontier and in relation to the metafrontier. We explore AES contracts heterogeneity, as they vary in terms of stringency and entail modifications in practices to varying extents of the farm. For both subgroups, whether AES subsidies are below or above 40€/ha of utilized agricultural area, we do not observe a causal effect of adoption on efficiency. On the other hand, our results indicate a decrease in efficiency of 11.55% between 2014 and 2020 due to the adoption of organic practices. We show that while organic farms are globally efficient relative to their own technology, they operate under a lower technology. This is observed by a significant decrease in the technological gap ratio for farms that adopted organic practices.

It is crucial to contextualize these findings within the scope of the CAP's multiple objectives and wider effects. A significant decline in farms' efficiency could potentially raise concerns about food security, farmers' livelihoods, and the competitiveness of the European Union's agricultural sector. Furthermore, if the tools employed to achieve Farm-to-Fork objectives result in reduced production, there is potential for leakage effects to occur in regions beyond the EU (Arvanitopoulos *et al.*, 2021; Henning and Witzke, 2021; Wesseler, 2022).

The organic standard was one of the pioneering environmental standards, but numerous other environmental standards have emerged since its development. In **Chapter 3**, we focus on two standards that we classify as intermediate environmental standards because they are less stringent than the organic standard. Contrary to the organic standard, farmers can change practices at the plot level without modifying the whole farming system and implement it within a production year. Intermediate environmental standards may be useful instruments to drive the evolution of farmers' practices given their higher adoption rate compared to the organic standard. Furthermore, unlike our previous study and the prevalent approach in the literature, in this chapter, we do not compare an environmental standard with conventional agriculture. We aim to explore whether farmers facing multiple choices of environmental standards are incentivized to adopt the most stringent standard.

Our empirical study is applied to wheat production in France. We focus on two standards aimed at favoring biodiversity that farmers can adopt at the plot level. While both standards require the presence of species habitats on farm plots, the more stringent standard also bans the most toxic pesticides. Our database includes 8,015 observations at the plot level for the period 2014-2020. The plots are operated by 278 farms located in the French region Poitou-Charentes. We assess the effects of adopting the most stringent environmental standard in terms of wheat yield and wheat quality (technical effects) and price received (economic effect). Regarding quality attributes, we focus on test weight and protein content since farmers receive monetary incentives to improve them through a marketing contract. Thus, a decrease in these two quality attributes would negatively affect the farm's economic outcome. We implement an endogenous switching regression, following the approach of Murtazashvili and Wooldridge (2016). This methodology accounts for the endogeneity of the explanatory variables in addition to the selection variable endogeneity.

This paper contributes to the scarce literature on farmers' choices when they face multiple environmental standards. It differs from prior research by examining the effect of the adoption of new practices and input use strategies at the plot level rather than at the farm level. It enables to consider the possibility that farmers could implement several environmental standards on their farms on different plots. In addition, we contribute to the literature on the effects of input use on farm outcomes through quality assessment. While it has been demonstrated that ignoring quality biases the results in analyses, only a few papers have considered how input use influences product quality (Babcock *et al.*, 1992; Cobourn *et al.*, 2013; Kawasaki and Lichtenberg, 2015).

Our results show that the prohibition of the most toxic pesticides at the plot level (via the adoption of a more stringent standard) has a negative impact on technical outcomes: it leads to an average decrease in yield of 2.5%, a reduction in test weight by 0.54 kg/hl, and a decline in protein content by 0.02 points. The adoption of a more stringent environmental standard results in an average increase in wheat price by €1.19/ton. The price premium associated with the more stringent environmental standard merely compensates for the detrimental effect of the standard adoption on quality.

Given the requirements of the more stringent standard (most toxic pesticides are prohibited), it seems to be an instrument worth considering to achieve the Farm-to-Fork objective of a 50% reduction in chemical pesticide risk by 2030. However, the results show that the monetary gains of this standard are marginal in comparison to the less stringent standard. Although the literature

highlights nonmonetary motivations underlying the adoption of environmental practices and standards (Ambec and Lanoie, 2008; Baumgart-Getz *et al.*, 2012; Lanoie and Llerena, 2015; Dessart *et al.*, 2019), it remains uncertain whether these nonmonetary motivations alone are substantial enough for the widespread adoption of this standard. Therefore, economic incentives should be carefully designed.

We further explore monetary and nonmonetary factors that support the adoption of environmental standards by exploring the second research question regarding the attributes of farming contracts that can foster their adoption. In **Chapter 4**, we explore the role of a key stakeholder of the supply chain, the agricultural cooperative, in encouraging the adoption of organic standards by their members. Agricultural cooperatives hold 40% of the total agri-food market shares (La coopération agricole, 2022), and thanks to their governance organization, they favor a close relationship with farmers. Farmers still face barriers to converting to organic farming in addition to economic barriers. Farm structure, the sociodemographic characteristics of farmers and behavioral factors influence the adoption of organic farming. Cooperatives can play a role in supporting the adoption of organic farming by offering contracts with monetary and nonmonetary attributes in line with farmers' preferences.

Given the scarcity of statistical data on contracts between farmers and cooperatives, we conducted a discrete choice experiment with all 70 winegrowers of a wine cooperative producing under the *Buzet* protected designation of origin (PDO). We examine several contract attributes whose objective is to encourage winegrowers to adopt organic farming: (1) the option to obtain a cooperative advisor to assess the impact of practice changes on the economic performance of the vineyard and the farm labor organization, (2) the opportunity to contract for only 50% of the vineyard area, and (3 and 4) the pricing formula, encompassing the potential to receive a 30% premium on the base price and access to a compensation mechanism to cope with yield loss. The chosen case study is particularly interesting because the cooperative, being located within a PDO territory and being the sole stakeholder producing wine in that territory, has the opportunity to ensure spatial continuity in the adoption of environmental practices if it can involve all of its members.

Our results show that winegrowers are more willing to adopt contracts where the base price is complemented by a 30% premium and where compensation for yield loss is included.

Winegrowers show no preferences for economic and labor organization advice; they may not wish for the cooperative to intrude into their economic and organizational management. Winegrowers' preferences for the option of a contract with only 50% of their vineyard area are mixed. We highlight that winegrowers have heterogeneous preferences regarding the adoption of organic farming. Winegrowers who declare that they enjoy testing risky solutions and feel ready to convert to organic farming are more willing to adopt a contract where organic farming is a requirement. With a latent class model, we identify three groups of winegrowers: *Organic lovers*, *Reluctant to organic* and *Reluctant to change*. Only 13% of the winegrowers would consider shifting to organic farming in their vineyards. This suggests that while cooperative farming contracts can be a potential instrument to increase the uptake of organic farming, they are not sufficient to scale up.

In the past, the cooperative successfully engaged all of its members in less ambitious environmental standards. The organic farming standard differs due to its high level of requirements, leading to a change in the whole production system. Another way to encourage winegrowers to adopt environmental practices is to incorporate these practices into the PDO's requirements. This approach offers a twofold advantage. It allows for the incorporation of environmental practices that take into account the specificities of the local territory and respond to its challenges. Additionally, it guarantees the adoption of these practices by all producers within the PDO territory, thus ensuring spatial continuity and the effective realization of environmental benefits.

While thus far, agri-environmental policy instruments have not succeeded in driving significant changes in farmers' practices, the European Commission stated that the 2023-2027 CAP program would be more ambitious from an environmental point of view (European Commission, 2017). Within this context, **Chapter 5** examines the effect of introducing a new instrument in the CAP, the eco-scheme, on changes in farmers' practices. The study of this instrument within the scope of this PhD thesis is motivated by the fact that the French government has chosen to provide access to the eco-scheme through two environmental standards: the organic standard and the HEV standard. With this study, we aim to gain insight into our third research question regarding the effect of incorporating environmental standards into public policies on farmers' practices.

Like AECM, the eco-scheme is a voluntary instrument but with a much larger budget, as 25% of the CAP first pillar budget is allocated to eco-schemes. Consequently, farmers who do not access eco-scheme subsidies will experience a significant reduction in their direct payment. The French eco-scheme is accessible through three noncumulative paths: i) the path of agro-ecological practices; ii) the path of environmental certification; and iii) the path of biodiversity friendly elements (Ministère de l'agriculture et de la souveraineté alimentaire, 2022). Each access path includes two requirement levels for conventional farms: a standard level entitling farmers to receive approximately €60/ha and a superior level with a higher payment of approximately €80/ha for those implementing more ambitious environmental practices. Additionally, there is a specific level for organic farmers, granting them a higher payment of €110/ha. The eco-scheme also incorporates a "hedge" bonus of €7/ha, which can be combined with the first two paths.

We assess the number of farmers who would have access to either the standard level of the scheme or the superior level without changing their farming practices. The analysis is carried out for different farming specializations based on individual data from the French Farm Accountancy Data Network (FADN) and complementary data. Our sample includes 4,699 farms. We exclude from our analysis farms that specialize in viticulture, arboriculture, and horticulture since they benefit very little from Pillar 1 CAP support (less than 2%) and consequently are very little concerned with the eco-scheme. For each farm, we calculate the indicator for each access path to determine their eligibility for eco-scheme subsidies. When data are missing to compute the indicators, we systematically underestimate the number of farms accessing the eco-scheme levels.

Our findings indicate that the French eco-scheme is unlikely to incentivize farmers to change their existing agricultural practices. Nearly all farms would reach the standard level of the eco-scheme through one of the three access paths without making any changes to their current practices. Moreover, a substantial proportion of farms would reach the superior level without modifying their practices. This is particularly true for livestock farms (91.4% for dairy cattle, 98.9% for sheep and goats, and 99.1% for beef cattle). Finally, our results show that the extra subsidy of €20 per hectare at the superior level appears to be too low to encourage farms specialized in cereals, oilseeds and protein crops and dairy farms to change their practices to reach the superior level.

The French eco-scheme is indeed tailored to ensure its accessibility to a vast majority of farmers, aligning with the explicit objective outlined in the French Government's National

Strategic Plan (Ministère de l'agriculture et de la souveraineté alimentaire, 2022). Nevertheless, this accessibility-oriented approach comes at the expense of its effectiveness in significantly mitigating the climate and environmental impacts of French agriculture. The lack of effectiveness does not stem from the instrument itself, which could have been incentivizing given that it represents 25% of the direct payments received by farmers. Instead, the lack of effectiveness results from the choice of easily attainable thresholds for many farmers and the minimal difference in subsidies between the standard and superior levels, which leads to a lack of incentives.

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Chapter 2. Does the adoption of environmental contracts affect farms' productivity and efficiency? An insight through the adoption of agri-environmental schemes (AES) and organic certification

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2.1. Introduction

The intensification of agricultural practices is a major driver of climate change and biodiversity loss. Worldwide, the agricultural sector accounted for 23% of total net anthropogenic greenhouse gases (GHG) from 2007 to 2016 (IPCC, 2019). The report of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) notes that about one million species are threatened with extinction (IPBES, 2019), and that agriculture and overexploitation of wild species are the main drivers of biodiversity decline (Maxwell *et al.*, 2016; Tilman *et al.*, 2017; IPBES, 2019). The intensification of agricultural practices harms biodiversity through various channels: habitat destruction and homogenization by spreading monoculture and removing hedgerows, use of chemical inputs (pesticides and fertilizers) and tillage (Benton *et al.*, 2003; Hautier *et al.*, 2009; Geiger *et al.*, 2010; Beketov *et al.*, 2013; Arslan, 2018; Sánchez-Bayo and Wyckhuys, 2019; Raven and Wagner, 2021)

A reduction in pesticides use by 50%, a decrease in fertilizer use by 20% and a conversion of 25% of the agricultural land under organic farming are the ambitious objectives set for 2030 by the European Union in terms of environment protection in the Green Deal and its Farm-to-Fork Strategy (European Commission, 2020). The Farm-to-Fork Strategy report recalls that it is urgent for agricultural production to reduce dependency on pesticides, reduce excessive use of fertilizers and reverse the decline in biodiversity. The report also highlights that the transition has to be sustained by the European Common Agricultural Policy (CAP). There exist already various agri-environmental policy instruments developed by the European Union to reduce the negative environmental impacts of food production (DeBoe, 2020). European agri-environmental policies are mainly based on conditioning CAP subsidies to environmental standards, subsidizing organic farming, and agri-environmental schemes (AES) – voluntary contracts between governments and farmers to produce environmental services in return for annual payments.

Recent social concerns about the negative effects of agricultural practices have brought new objectives to the CAP. However, historical and still relevant objectives for the CAP are to ensure food supply, support farmers' income and increase the competitiveness of the agricultural sector. Thus, questions can be raised as to which instruments future CAP programs will use to meet environmental challenges and what effects they will have on farms' productivity. In this paper, we aim at assessing the impact of two existing instruments on farms' productivity that will probably be used by future CAP programs to incentivize farmers to adopt

environmental practices, namely, AES and organic subsidies. We will refer to both instruments as environmental contracts. From a public policy point of view, the goal is to understand whether government support toward the voluntary adoption of environmental practices affects the efficiency and the productivity of the participating farms. Our analysis focuses on French crop farms from the Poitou-Charentes region during the 2014-2020 CAP program. We estimate farms' aggregate productivity using a modified Malmquist index approach, and focus on the technical efficiency component. We adopt a stochastic frontier (SF) model. To assess the effect of the adoption of AES and organic farming, we estimate the average treatment effect on the treated (ATT) using a difference-in-differences approach.

AES and organic contracts have similar characteristics: their adoption is voluntary and farmers receive monetary incentives to do so. They also differ on several points. First, the requirements for organic farming are more stringent than the ones for AES contracts. Second, while AES rely on five-year contracts, the adoption of organic farming is based on a two-year conversion period that commits farms to production practices in the long term. Finally, the monetary incentive mechanisms differ. In the case of AES contracts, farmers receive subsidies to compensate for the profit loss due to the adoption of environmental practices. For organic farming, there are two monetary incentives. First, organic producers in France receive subsidies during the conversion period to partially offset the temporary reduction in profitability, and after conversion (at lower rates) to reduce market risks and support organic practices. Second, organic products receive a price premium thanks to product differentiation in the market.

A vast literature aims at evaluating the impact of subsidies on farms' technical efficiency (see Minviel and Latruffe (2016) for a meta-analysis of the effects of public subsidies on farms' technical efficiency). There is no consensus in the literature on the impact of the adoption of organic farming on technical efficiency despite the existence of numerous efficiency analyses (see Lakner and Breustedt (2017) for a review). Some studies show that, on average, organic certification increases technical efficiency (Tzouvelekas *et al.*, 2001; Tzouvelekas *et al.*, 2002; Oude Lansink, 2002; Tiedemann and Latacz-Lohmann, 2013; Grovermann *et al.*, 2021), while others find a negative impact (Sipiläinen and Oude Lansink, 2005; Kumbhakar *et al.*, 2009; Serra and Goodwin, 2009). There are also studies that do not find a significant difference (Mayen *et al.*, 2010; Sauer, 2010; Grovermann *et al.*, 2021). The different conclusions can be explained by many reasons. First, studies are conducted on different kinds of productions (e.g., olive, crop, dairy) in different western countries (European countries and the United States). Second, different kinds of data are used: some studies rely on panel data, whereas others

consider cross-sectional data. Third, some studies rely on SF analysis (Tzouvelekas *et al.*, 2001; Tzouvelekas *et al.*, 2002; Sipiläinen and Oude Lansink, 2005; Kumbhakar *et al.*, 2009; Mayen *et al.*, 2010; Tiedemann and Latacz-Lohmann, 2013; Grovermann *et al.*, 2021), whereas other studies resort to alternative efficiency estimation strategies such as data envelopment analysis (Oude Lansink, 2002; Sipiläinen and Huhtala, 2013). Fourth, while some analyses consider a unique frontier for both technologies (Sipiläinen and Huhtala, 2013; Aldanondo-Ochoa *et al.*, 2014), most of them consider two different frontiers. Finally, numerous studies do not address the organic farming adoption-selection bias. Sipiläinen and Oude Lansink (2005) used the Heckman-type correction by appending the inverse Mill's ratio to address selection bias. However, it has been shown that this approach is not suitable for non-linear models such as the SF approach (Greene, 2010). To take into account the endogeneity of the decision to adopt organic practices, Kumbhakar *et al.* (2009) jointly estimate the production frontier and the technology choice. Mayen *et al.* (2010) and Tiedemann and Latacz-Lohmann (2013) rely, respectively, on propensity score matching and Euclidean-distance matching to address the selection bias.

A large share of the literature on AES aims at understanding the determinants of AES adoption. The number of studies analyzing the impact of AES adoption on productivity is small. Dakpo *et al.* (2022) estimate technical efficiency for farms who adopted AES and conventional farms, accounting for production heterogeneity with a latent class model. Mary (2013) assesses the impact of subsidies on total factor productivity (TFP) change and shows that AES payments do not have a significant effect. Two recent studies, Baráth *et al.* (2020) and Mennig and Sauer (2020), aim at comparing TFP change between AES adopters and non-adopters. They obtain slightly different results. Baráth *et al.* (2020) find no significant effect of AES adoption on either TFP change or its components for Slovenian farms. Mennig and Sauer (2020) find similar results for Bavarian dairy farms, but highlight a positive effect of AES adoption on TFP change for Bavarian arable farms. Moreover, they show that AES affect significantly and positively the technical efficiency of arable farms.

Our paper contributes to the previous empirical literature mentioned above by comparing the effect of two CAP environmental contracts, organic farming and AES, on farms' productivity and efficiency. From a public policy point of view, it is an important question. The objective is to understand if these two instruments could allow achieving the multiplicity of the CAP objectives such as environment conservation, food supply and farmers' income security.

Our analysis also contributes to the existing literature from a methodological point of view. First, we implement the stochastic metafrontier techniques proposed by Huang *et al.* (2014). To our knowledge, no study has applied stochastic metafrontier methods to investigate the effect of AES or organic adoption on farms' efficiency. We can only mention the study by Beltrán-Esteve and Reig-Martínez (2014), which applies a metafrontier methodology based on data envelope analysis. Metafrontier models allow one to compare technical efficiency of farms within each group (conventional, organic and AES) as well as between groups in relation to the sector as a whole. Second, in contrast to previous literature on organic farming which compares a group of conventional farms to a group of organic farms, we focus on farms adopting organic farming during the period under study and examine the evolution of their efficiency. Our third and fourth methodological contributions concern exclusively the organic literature, as they have already been implemented by previous studies for AES farms: we address selection bias toward the adoption of organic farming with a difference-in-differences estimator; and we extend the existing literature by analyzing aggregate productivity change and its components. It is of interest for policymakers to know how the adoption of the organic certification affects farms' technical efficiency. However, a broader knowledge of the effects of the adoption of the organic certification on farms' productivity will allow policymakers to better identify the channels through which the organic certification exerts its impact. To the best of our knowledge, no previous study has analyzed the effect of organic farming adoption on aggregate productivity change and its components. The only paper related to this issue is Baležentis (2015), which aims at determining the drivers of TFP growth. He shows that the adoption of organic certification has no significant effect on TFP change.

The rest of the article is organized as follows. After presenting the background (section 2.2), we describe the data used and discuss summary statistics (section 2.3). We explain our empirical strategy based on an SF model and a difference-in-differences estimator (section 2.4). Finally, we present and discuss our results (section 2.5) and provide concluding remarks (section 2.6).

2.2. Background

The present study analyzes farms in the French region of Poitou-Charentes. This region plays a significant role in crop production within France. In 2014, 55% of the arable land was dedicated to the production of cereals and 18% to the production of oleaginous crops (Agreste, 2015).

AES Contracts and Adoption in Poitou-Charentes

AES are one of the CAP instruments to encourage the voluntary adoption of environmental practices by farmers. They consist of five-year contracts where farmers receive subsidies to compensate for the profit loss due to the adoption of environmental practices. Farmers receive payments on a yearly basis and controls can be conducted to verify that the practices that the farmers have committed to implement are indeed carried out. The second pillar of the CAP finances AES to the extent of 75%, while the remaining 25% is co-financed by member-states (Ministère de l'Agriculture et de la Souveraineté Alimentaire, 2020). AES have a long history in the CAP, becoming mandatory for the member states' rural development plans in the 1992 CAP reform. AES contracts have evolved over the years, gaining importance in CAP programs. During the 2014-2020 CAP program, the total amount of public aid devoted to AES doubled compared to the preceding CAP program (2007-2013). AES corresponding to the 2014-2020 CAP program were implemented in 2015.

The total AES budget for the Poitou-Charentes region was €177 million for the 2014-2020 CAP (Région Nouvelle-Aquitaine, 2020). From 2015 to 2019, there were 5,646 contracts signed by 3,428 farms. Thus, 13% of the farms in the region have signed an AES contract and 11% of the agricultural area of the region is under an AES contract (Région Nouvelle-Aquitaine, 2020). While an AES contract could be signed at any time between 2015 and 2019, 60% of the farms did so in 2015 when AES contracts were first offered for the CAP program under study. In the following years, the new AES contracts signed represented on average 10% of the contracts for the period analyzed (Région Nouvelle-Aquitaine, 2020). In Poitou-Charentes, producers received between €76 per ha to €510 per ha depending on the contracted AES.

AES contracts can be classified into three main types: localized measures, system measures, and measures to protect genetic resources. Localized measures AES aim at preserving wetlands, biodiversity, water quality, soils, or landscapes. These AES contracts can require a variety of practices on the contracted plots: soil coverage and management, grassland management, irrigation management, hedge and tree management, crop protection and fertilization management. System measures are AES contracts introduced in 2015 which, contrary to the localized measures, are contracted on the entire farm area and aim at globally engaging the farm towards the adoption of environmental practices by requiring crop diversification, pesticides reduction and a rational fertilization management. Finally, AES contracts based on measures to protect genetic resources aim at protecting endangered breeds and plants, as well as bees (Ministère de l'Agriculture et de la Souveraineté Alimentaire, 2020). This type of AES is very

marginal in Poitou-Charentes, as it represents 2% of the total budget allocated to AES and benefits only a few beekeepers and breeders. Localized AES and system measures AES are predominant, as they account for 44% of financial resources for 30% of the land area, and 53% of financial resources for 70% of the land area, respectively. The two most adopted localized AES contracts are related to the creation and maintenance of a floral or faunal interest cover and the absence of fertilization of grasslands. Thus, the adoption of an AES contract leads to a modification of the technology compared to conventional technology, by imposing restrictions on input use and the implementation of specific practices.

Organic Farming in Poitou-Charentes

In France, organic products are subject to strict regulatory requirements and frequent inspections. To be certified as organic, products must come from a certified organic farm. The organic certification requires a two-year conversion process where farmers apply organic farming practices before being allowed to label their products as organic. French public policies recognized organic farming in 1981 and the requirements were harmonized at the European level in 1992.

The main constraints of the organic farming specifications are based on the prohibition of the use of synthetic pesticides and fertilizers. The adoption of organic practices leads to large modifications of the farming system. Despite the early recognition of organic farming, it has long remained a niche market. It is only recently that the dynamics of conversion to organic agriculture have increased. In Poitou-Charentes, 6% of the agricultural land was cultivated under organic practices in 2019, representing an increase of nearly 30% of the area compared to 2018 (InterBio Nouvelle-Aquitaine, 2021). Organic farms and farms converting to organic practices received subsidies from the second pillar of the CAP. During the previous CAP program, from 2014 to 2020, farms situated in Poitou-Charentes received 300€/ha/year during the two-year conversion period and 160€/ha/year once they were certified (Chambre d'agriculture Nouvelle-Aquitaine, 2018).

2.3. Data

The database for the present study is composed of specialized crop farms in Poitou-Charentes. In our sample, on average, crop production represents 94% of farms' total production in value. Anonymized farm-specific data was obtained from the accounting firm CERFRANCE Poitou-Charentes. Beyond traditional accounting information, the dataset includes information on farms' adoption of organic farming and AES and farms' characteristics. Unlike a census, farmers' engagement with the accounting firm is voluntary; consequently, our full database is an unbalanced panel dataset from 2014 to 2020. Due to our choice of identification strategy, which relies on a difference-in-differences approach (see section 4.2), we only consider farms present in the sample in both 2014 and 2020. This allows us to define for each farm a pre-treatment period in 2014, when none of the farms had adopted an environmental contract, and a post-treatment period in 2020, when some of the farms were under an environmental contract. Our dataset includes 4,424 observations on 690 different farms. This sample represents 11% of the region's farms specializing in crop production (Recensement agricole, 2020). Table 2.1 presents the panel structure of the database, showing that 65% of the farms are present every year from 2014 through 2020. Since the choice of accounting firm is not related to the adoption of environmental contracts or to farms' productivity, it seems reasonable to assume that there is no attrition bias in our sample.

Table 2.1. Panel structure of the full database

Panel length (in years)	2	3	4	5	6	7
Frequency	1	15	30	53	145	446
Percentage	<1%	2%	4%	8%	21%	65%

Our focus on a particular region and farm specialization enables us to compare farms operating within a more uniform environment and a more homogeneous mix of production technologies than possible with the national farm accountancy data network (FADN) database. The latter database only contains information for around fifty farms specializing in crop production in the Poitou-Charentes region. During the period under study, 102 farms adopted an AES contract, representing 15% of the farms in our sample. In addition, 34 farms adopted organic contracts¹

¹ The adoption of an organic contract coincides with a farm's conversion to organic practices. The organic certification will be obtained two years later.

from 2015 onwards and 10 farms adopted organic practices before this date. The latter were excluded from the sample because our focus is on the effect of environmental contract adoption. We refer to farms that did not adopt environmental contracts as conventional farms.

Tables 2.2 and Table 2.3 present descriptive statistics by groups of farms (conventional, AES, and organic) in 2014 and 2020, respectively. Total farm output (in terms of sales) and materials (which include fertilizers, pesticides, energy, and other miscellaneous inputs) both take into account inventory changes. All monetary values were deflated by output or input price indices with base year 2015 (Insee, 2022). Output price indices are available at the national level and input price indices are available at the regional level. Due to the lack of organic-specific price indices, identical indices are used for conventional, AES, and organic farms. The land variable is the utilized agricultural area (UAA) of each farm. We compute the Herfindahl-Hirschman Index² to assess the crop diversity of the farms.

In 2014, farms that would later adopt AES or organic contracts were similar to the group of conventional farms (i.e., no significant differences were detected between the two groups and conventional farms over the selected characteristic in Table 2.2). This fact suggests that farming systems are comparable before the adoption of environmental contracts. These results differ from a branch of the literature highlighting for AES and organic contracts differences on farm observed characteristics before adoption (Mayen *et al.*, 2010; Baráth *et al.*, 2020; Mennig and Sauer, 2020; Dakpo *et al.*, 2022). This observation may be explained by two phenomena. First, it may result from our sample choice, which includes only farms highly specialized in crop production; therefore, farms are very homogeneous before the adoption of an environmental contract. Second, farms adopting AES contracts or organic farming after 2014 were not pioneers. AES have existed for over 20 years in the CAP. In the region under study, a wave of conversion to organic farming was observed starting in 2015. In one year, from 2018 to 2019, the cultivated area in organic farming increased by nearly 30% (InterBio Nouvelle-Aquitaine, 2021).

In 2020, average output per hectare in organic farms was significantly smaller than in conventional farms. This difference is observed despite the fact that we have deflated output values for conventional and organic farms by same price indexes due to lack of information on

² The Herfindahl-Hirschman Index, also known as the Simpson diversity index in ecology, has been used in the agronomic literature to measure the extent of crop diversification (Basavaraj *et al.*, 2016; Adjimoti and Kwadzo, 2018). It is calculated with the following formula: $Index = 1 - \sum_{i=1}^n P_i^2$, where P_i is the acreage share of the crop i in the UAA and n the number of crops considered. The index increases as diversification increases.

organic-specific prices. As organic products typically receive price premiums in the market, using the same price deflators for organic as for conventional output should overestimate the true organic output quantity. In addition, organic farms tended to own more capital per hectare than conventional farms. Both results are expected, as it has been shown that the adoption of organic practices negatively affects crop yields (de Ponti *et al.*, 2012; Seufert *et al.*, 2012; Reganold and Wachter, 2016; Smith *et al.*, 2020) and organic practices rely more on agricultural machinery, especially for weed control, to compensate for not using pesticides (Turner *et al.*, 2007; Benaragama and Shirliffe, 2013). In addition, the Herfindahl-Hirschman Index for organic farms was significantly higher than for conventional farms, indicating higher crop diversification among the former group. These observations imply that the agricultural production system was altered by the adoption of practices that comply with the specifications of organic farming. However, for farms adopting AES contracts, we did not observe any significant differences in 2020, after the adoption of the contract, with respect to conventional farms (Table 2.3). The only exception was subsidies, which is an expected result.

The comparison of conventional farms shows a decrease in the value of total output between 2014 and 2020, a result confirmed by an analysis of main crop yields. At the same time, we observe an increase in the UAA, which highlights a trend toward larger farms by area, and a decrease in the value of capital. The observed decrease in capital can be explained by several factors. Firstly, there are cycles of investment in agriculture depending on the economic context and few investments occurred during the period under analysis. Secondly, on average conventional farms tended to outsource an increasing share of farm tasks through hired custom work (84.88€/ha in 2014 to 102.67€/ha in 2020). Thirdly, obsolescence and depreciation of durable assets reduce the value of capital yearly.

Table 2.2. Descriptive statistics – 2014

Variable	Conventional farms	AES farms		Organic farms	
	mean (standard deviation)	mean (standard deviation)	<i>Comparison of mean with conventional farms</i>	mean (standard deviation)	<i>Comparison of mean with conventional farms</i>
# observations	554	102		34	
<i>Production function</i>					
Total output ^a (€/ha)	1,120.91 (291.49)	1,140.42 (292.53)	<i>n.s.</i>	1,073.47 (336.64)	<i>n.s.</i>
Labor (Man-unit)	1.34 (0.56)	1.37 (0.67)	<i>n.s.</i>	1.31 (0.59)	<i>n.s.</i>
Land (UAA in ha)	153.84 (64.54)	153.66 (55.05)	<i>n.s.</i>	145.88 (55.37)	<i>n.s.</i>
Materials ^a (€/ha)	928.45 (223.67)	906.08 (226.05)	<i>n.s.</i>	957.11 (273.13)	<i>n.s.</i>
Capital ^a (€/ha)	767.56 (558.86)	767.67 (578.49)	<i>n.s.</i>	696.80 (677.22)	<i>n.s.</i>
<i>Source of within group inefficiency</i>					
Share of employees (%)	7.75 (16.23)	6.13 (13.96)	<i>n.s.</i>	10.82 (22.02)	<i>n.s.</i>
Irrigation (dummy)	0.26 (0.44)	0.30 (0.46)	<i>n.s.</i>	0.26 (0.45)	<i>n.s.</i>
<i>Source of between group inefficiency</i>					
AES subsidies / Farm UAA (€/ha)	0.00 (0.00)	0.00 (0.00)	<i>n.s.</i>	0.00 (0.00)	<i>n.s.</i>
Herfindahl-Hirschman Index	0.81 (0.09)	0.81 (0.09)	<i>n.s.</i>	0.81 (0.12)	<i>n.s.</i>

^aValues are deflated by yearly index prices.

Wilcoxon rank-sum tests are performed; *, **, *** indicate significance at the 10%, 5% and 1% levels, respectively; *n.s.* stand for non-significant.

Table 2.3. Descriptive statistics – 2020

Variable	Conventional farms	AES farms		Organic farms	
	mean (standard deviation)	mean (standard deviation)	<i>Comparison of mean with conventional farms</i>	mean (standard deviation)	<i>Comparison of mean with conventional farms</i>
# observations	554	102		34	
<i>Production function</i>					
Total output ^a (€/ha)	889.55 (285.77)	885.71 (257.74)	<i>n.s.</i>	772.42 (388.11)	**
Labor (Man-unit)	1.27 (0.53)	1.30 (0.57)	<i>n.s.</i>	1.27 (0.47)	<i>n.s.</i>
Land (UAA in ha)	164.13 (73.15)	164.32 (63.16)	<i>n.s.</i>	142.36 (48.50)	<i>n.s.</i>
Materials ^a (€/ha)	886.48 (238.34)	850.77 (204.08)	<i>n.s.</i>	850.85 (283.69)	<i>n.s.</i>
Capital ^a (€/ha)	402.48 (397.72)	390.83 (406.68)	<i>n.s.</i>	622.34 (564.25)	**
<i>Source of within group inefficiency</i>					
Share of employees (%)	6.47 (14.91)	5.22 (12.21)	<i>n.s.</i>	7.00 (17.35)	<i>n.s.</i>
Irrigation (dummy)	0.19 (0.40)	0.22 (0.41)	<i>n.s.</i>	0.26 (0.45)	<i>n.s.</i>
<i>Source of between group inefficiency</i>					
AES subsidies / Farm UAA (€/ha)	0.00 (0.00)	39.40 (43.40)	***	0.00 (0.00)	<i>n.s.</i>
Herfindahl-Hirschman Index	0.85 (0.09)	0.86 (0.07)	<i>n.s.</i>	0.91 (0.07)	***

^aValues are deflated by yearly index prices.

Wilcoxon rank-sum tests are performed; *, **, *** indicate significance at the 10%, 5% and 1% levels, respectively; *n.s.* stand for non-significant.

2.4. Methodology

2.4.1. Estimation of stochastic production frontier, total factor productivity and its components

We adopt the SF model to estimate production frontiers and measure technical efficiency. It is a parametric method, first proposed by Aigner *et al.* (1977) and Meeusen and van Den Broeck (1977). The SF model is composed of two error terms and is specified as follows:

$$\ln Y_{it}^k = f(\ln X_{it}^k; \beta^k) + v_{it}^k - u_{it}^k \quad (1)$$

where Y_{it}^k denotes the output quantity of farm i with the k technology at time t , $f(\cdot)$ describes

the production frontier, X_{it}^k represents the vector of transformations of input quantities, and β^k is a vector of parameters to be estimated. The error term is composed of a two-sided stochastic term v_{it}^k accounting for statistical noise, and a nonnegative stochastic term u_{it}^k representing inefficiency. We assume v_{it}^k is normally distributed, $v_{it}^k \sim N(0, \sigma_{vk}^2)$ and u_{it}^k follows a truncated normal distribution $u_{it}^k \sim N^+(\mu_{it}^k, \sigma_{uk}^2)$. In addition, v_{it}^k and u_{it}^k are assumed to be uncorrelated. Inefficiency is computed in an output-oriented model, i.e., a farm is considered inefficient if a higher level of output could be produced with a given quantity of input. We estimate a frontier for each farm group k (conventional, AES, and organic) because, as highlighted in section 2, they rely on different technologies due to input restrictions and specific practices implementation.

For the production technology specification, we consider one output, the total output of the farm in terms of sales (Y), because the farms in our sample are highly specialized in crop production (94% of the total production in value). In addition, we consider four inputs; namely, total labor (X_W), land dedicated to agricultural activities (X_L), materials (X_M) which include fertilizers, pesticides, energy, and other miscellaneous inputs, and capital (X_K). X_W is expressed in full-time equivalent annual labor units, X_L in hectares, and X_M and X_K in monetary value. As mentioned previously in the data section, all monetary values were deflated by output or input price indices with base year 2015 (Insee, 2022). We specify the technology as a translog production function, as follows:

$$\ln Y_{it}^k = \beta_0^k + \sum_n \beta_n^k \ln X_{nit}^k + \frac{1}{2} \sum_n \sum_l \beta_{nl}^k \ln X_{nit}^k \ln X_{lit}^k + \sum_n \beta_{nt}^k t \ln X_{nit}^k + \beta_t^k t + v_{it}^k - u_{it}^k \quad (2)$$

with $\beta_{nl}^k = \beta_{ln}^k$ for $n, l = W, L, M, K$.

We account for potential non-neutral technical change by including interaction terms between time and input variables in the production function.

It is a common practice in efficiency analysis to rely on inputs and outputs expressed in monetary values because of their availability. Nevertheless, when estimating efficiency scores with monetary values instead of physical quantities, the efficiency score not only represents technical efficiency, but also reflects allocative efficiency to a certain extent. We deflated monetary values to control for the price effect. Assuming that farmers face the same yearly prices for inputs and output allows us to recover implicit physical quantities.

Besides the interest in estimating farms' inefficiency scores, from a public policy point of view, it is beneficial to identify the drivers of inefficiency. Several models accounting for the

determinants of inefficiency have been developed (Kumbhakar *et al.*, 1991; Reifschneider and Stevenson, 1991; Huang and Liu, 1994). Here, we follow the most commonly applied model proposed by Battese and Coelli (1995). It states that the technical inefficiency can be explained by a set of variables z_{it}^k , as follows:

$$u_{it}^k = z_{it}^k \delta^k + w_{it}^k \quad (3)$$

where δ^k is a vector of parameters to be estimated and w_{it}^k is defined by the truncation of the normal distribution $N(0, \sigma_{uk}^2)$, such that the point of truncation is $-z_{it}^k \delta^k$. It follows that $u_{it}^k \sim N^+(z_{it}^k \delta, \sigma_{uk}^2)$. In our setting, the explanatory variables included in z_{it}^k are 14 regional dummies, share of employed workers (as opposed to family labor), usage of irrigation (dummy), and size of the farm (in ha).

The SF model (equation 2) and the model accounting for the technical inefficiency effects (equation 3) are estimated simultaneously by maximum likelihood method using the frontier R package developed by Coelli and Henningsen (2013).

To measure productivity change (PC), we follow the methodology developed by Orea (2002)³ that allows for the decomposition of a Malmquist productivity index (MPI) into technical efficiency (TE), technical change (TC), and scale economies. While the MPI is the most popular productivity measurement instrument in the absence of price data (Balk *et al.*, 2020) it is not an indicator of TFP because it is not a multiplicatively-complete⁴ index (O'Donnell, 2012). The TE of farm i with the k -th technology at time t is defined as:

$$TE_{it}^k = \exp(-u_{it}^k) \quad (4)$$

Thus, the first component, the technical efficiency change (TEC) of farm i between the base period s and the reference period t is calculated as follows:

$$TEC_{t,t/s}^k = \frac{TE_{it}^k}{TE_{is}^k} \quad (5)$$

TC for farm i with the k technology between period s and t is the geometric mean of the partial derivatives with respect to time of the production function:

³ Equations (5) to (8) are derived in detail in Orea (2002) and Coelli *et al.* (2005, pp. 291-293 and 300-302).

⁴ O'Donnell (2012, p. 875) defines a multiplicatively-complete TFP index as one that can be derived from any TFP index that can be written as a ratio of an output quantity index to an input quantity index. The Malmquist productivity index first introduced by Caves, Christensen, and Diewert (1982) is not multiplicatively-complete.

$$TC_{i,t/s}^k = \exp\left(\frac{1}{2}\left[\frac{\partial \ln Y_{is}^k}{\partial s} + \frac{\partial \ln Y_{it}^k}{\partial t}\right]\right) \quad (6)$$

The last component of PC is the scale change (SC) introduced by Orea (2002). SC for farm i with the k technology between period s and t is defined as follows:

$$SC_{i,t/s}^k = \exp\left(\frac{1}{2}\sum_{n=1}^4 [\varepsilon_{nis}^k SF_{is}^k + \varepsilon_{nit}^k SF_{it}^k] * \ln\left(\frac{x_{nit}^k}{x_{nis}^k}\right)\right) \quad (7)$$

where $SF_{is}^k = (\varepsilon_{is}^k - 1)/\varepsilon_{is}^k$, $\varepsilon_{is}^k = \sum_{n=1}^N \varepsilon_{nis}^k$ and $\varepsilon_{nis}^k = \frac{\partial \ln Y_{is}^k}{\partial \ln x_{nis}^k}$ which is the output elasticity with respect to each input.

Finally, PC is the sum of the three components:

$$PC_{i,t/s}^k = TEC_{i,t/s}^k + TC_{i,t/s}^k + SC_{i,t/s}^k \quad (8)$$

2.4.2. Estimation of stochastic metafrontier, technology gap ratio and TE with respect to the metafrontier

Most of the studies comparing TE for organic farms and conventional farms define two different frontiers for each group and thus measure differences in efficiencies in relation to the production frontier of the farms' own type (Lakner and Breustedt, 2017). This type of analysis enables the discussion of farms' TE in relation to their respective frontiers within each group, but it does not allow for comparisons between groups with respect to the entire sector. On the other hand, with the exception of Dakpo *et al.* (2022), most studies comparing the TE of AES farms and conventional farms assume that both types of farms have identical technologies and, therefore, compare them based on a single frontier. To avoid making this assumption while being able to compare farms' TE results between different groups not sharing the same technology, we apply a stochastic metafrontier approach. The metafrontier can be described as the frontier that envelops all production technologies. This methodology has been previously used in agricultural economics analysis (Melo-Becerra and Orozco-Gallo, 2017; Alem *et al.*, 2019; Martinez Cillero *et al.*, 2021; DeLay *et al.*, 2022; Owusu and Bravo-Ureta, 2022).

The empirical application of stochastic metafrontiers was first proposed by Battese *et al.* (2004) and O'Donnell *et al.* (2008). Their approach is based on a two-step procedure. In the first step, they estimate group-specific frontiers using an SF model, and in the second step, they utilize

mathematical programming techniques to estimate the metafrontier. We apply the methodology developed by Huang *et al.* (2014), who estimate the metafrontier in the second step as stochastic. This approach has two advantages over the aforementioned methodologies. First, it incorporates stochastic factors and statistical noise into the estimation of the metafrontier. Second, the metafrontier estimates obtained from this approach possess meaningful statistical properties.

In the first step, a frontier is estimated for each group of farms (conventional, AES, and organic) following the methodology described in section 4.1. In the second step, the metafrontier M is estimated as follows:

$$\hat{f}^k(\ln X_{it}^k; \beta^k) = f^M(\ln X_{it}^k; \beta^M) + v_{it}^{kM} - u_{it}^{kM} \quad (9)$$

where $\hat{f}^k(\ln X_{it}^k; \beta^k)$ is the estimate of each group frontier from the first step in Equation (1). In Equation (9), X_{it}^k , i, t and k are defined in the same way as in Equation (1). $f^M(\cdot)$ represents the metafrontier and β^M is a vector of the metafrontier parameters to be estimated. The error term is composed of a two-sided stochastic term v_{it}^{kM} accounting for statistical noise and a nonnegative stochastic term u_{it}^{kM} representing the technology gap. The technology gap component is modeled as a set of explanatory variables like in Equation (3) following the Battese and Coelli (1995) model. In our setting, we include the Herfindahl-Hirschman Index (which accounts for farms' crop diversity) and the value of AES subsidies per hectare as explanatory variables. We define TE in the same way as in Equation (4), indicating the distance of each farm to its respective technology frontier⁵.

To compare technology efficiencies we compute the technology gap ratio (TGR), which represents the distance between the technology frontier and the metafrontier. It is specified as follows:

$$TGR_{it}^k = \exp(-u_{it}^{kM}) \quad (10)$$

Finally, to compare farms using different technologies in relation to the entire sector, we calculate the distance of each farm to the metafrontier, which is referred to as MTE. It is specified as follows:

$$MTE_{it}^k = TGR_{it}^k * TE_{it}^k \quad (11)$$

⁵ As previously discussed, Equation (4) measures TE in relation to the respective frontier within each group, but it does not allow for comparisons between groups with respect to the entire sector.

2.4.3. Identification strategy with a difference-in-differences approach

We estimate separately the effects of adopting AES and organic contracts on farms' efficiency and productivity, but we follow the same identification strategy, presented hereafter. The treated group ($D = 1$) is composed of farms that adopted an environmental contract after 2014, and the control group ($D = 0$) consists of conventional farms.

Selection bias arises because the adoption of environmental contracts is voluntary. A large literature has studied the determinants of the adoption of AES and organic farming (for meta-analyses and literature reviews see Latruffe and Nauges (2013); Lastra-Bravo *et al.* (2015); Zimmermann and Britz (2016); Dessart *et al.* (2019)). This literature highlights several categories of determinants, including farm structure (e.g. farm size, farm location, share of family labor) and farmer characteristics (e.g. age, education level, risk aversion, sensitivity to environmental issues). In addition, Pietola and Lansink (2001) show that the adoption of organic farming is more likely among farms having low yields. These determinants of the adoption of environmental contracts also affect farms' productivity. They act as confounding factors and need to be controlled for in the identification strategy. Within these potential confounding factors, some are observable while others are unobservable. Descriptive statistics in 2014, presented and discussed in the previous section, highlight that farming systems are comparable before the adoption of environmental contracts. This is a strength of our sample, which allows us to avoid employing a selection bias control method on observable characteristics. To control for selection bias on unobservable confounding factors, such as risk aversion or sensitivity to environmental issues, we apply a difference-in-differences approach and estimate the ATT.

For both the treated and the control group, we define two potential outcomes: $Y(1)$ if the farmer adopts an environmental contract during the period under study and $Y(0)$ if the farmer does not. We also define *pre* as the period before the implementation of the treatment and *post* as the period after its implementation. According to the difference-in-differences approach, the effect of the adoption of an environmental contract can be identified by comparing the change in the expected outcome of the treated group between periods *pre* and *post*, $E[Y_{post}(1) - Y_{pre}(0) | D = 1]$, to the counterfactual change in the expected outcome if farmers would have not adopted the environmental contract $E[Y_{post}(0) - Y_{pre}(0) | D = 1]$. The counterfactual case is not observed, but under the parallel trend assumption we obtain the following equality: $E[Y_{post}(0) - Y_{pre}(0) | D = 1] = E[Y_{post}(0) - Y_{pre}(0) | D = 0]$.

According to the parallel trend assumption, the expected outcome difference between the treated and control group would have been constant over time in the absence of treatment. It states that the adoption of environmental contracts does not depend on time-varying factors. It seems reasonable to consider as fixed over the short period under study the determinants of the adoption of environmental contracts identified in the literature, such as farms' structure and farmers' characteristics. Therefore, with a difference-in-differences approach the ATT can be defined as follows:

$$ATT = E[Y_{post}(1) - Y_{pre}(0) | D = 1] - E[Y_{post}(0) - Y_{pre}(0) | D = 0] \quad (12)$$

To recover the ATT effectively by a difference-in-differences approach, the Stable Unit Treatment Value Assumption (SUTVA) should also be met. The SUTVA assumption requires the treatment to be homogenous among the treated group, in our case the adoption of either AES or organic farming. The SUTVA also requires the treatment to have no effect on the non-treated unit outcome. The adoption of environmental contracts is low worldwide, the scale at which agricultural prices are determined. We believe that the adoption of environmental contracts has no effect on the prices of inputs and outputs and, hence, no effect on input and output choices and thus neither on their productivity. In addition, AES contracts are designed to respect the World Trade Organization green box requirements (i.e. subsidies must not distort trade).

In our framework, 2014 is the pre-treatment period and 2020 is the post-treatment period. For each environmental contract, we compare efficiency and productivity for adopters to conventional farms. We apply the difference-in-difference estimator to compute the ATT and test for the significance of the effect of environmental contract adoption by applying a Wilcoxon rank-sum test.

2.5. Results and Discussion

To test whether the three groups have different technologies and thus justify the estimation of a production frontier per group, we perform the likelihood-ratio test proposed by Battese *et al.* (2004). Since the statistical value of the test is significant (142.765***), we reject the null hypothesis that conventional, AES and organic farms have the same technology. We also perform the test solely on conventional and AES farms, which is significant (79.379***) and therefore indicates that different frontiers should be estimated for conventional and AES farms.

The estimates from the SF models for conventional, AES and organic farms are presented in table 2.4. For the three models, the variance of the inefficiency term represents more than 85% of the total variance, supporting the implementation of SF models. Data were mean-corrected before estimation to allow the interpretation of first-order parameters as the elasticities at the sample mean. Elasticities at the sample mean for all groups follow a similar pattern. The largest elasticity at the sample mean data point corresponds to materials, followed by land. The sum of the four production elasticities is larger than one for the conventional technology (1.04), suggesting slightly increasing returns to scale, whereas it is lower than one for AES and organic technology (respectively 0.90 and 0.98), indicating moderate to slightly decreasing returns to scale. Time coefficients are significant and suggest a technical regress of the same order of magnitude for conventional farms and farms adopting the AES technology over the period of study, respectively 1.50% and 1.40% per year. Technical regress is twice as large for farms adopting the organic technology. The interaction term between time and materials is significantly positive for the conventional technology, indicating that TC has been materials-saving. To a lesser extent, TC has also been capital-saving for the conventional technology.

Regarding the inefficiency term, results show that for the conventional technology, a higher share of hired labor and the absence of an irrigation system are associated with higher inefficiency scores. To a lesser extent, inefficiency is negatively affected by farmland size, highlighting that bigger farms tend to be more efficient. The latter result also applies to the AES farms. Most regional dummies parameters are significant, indicating soil quality effects on inefficiency; although they are not reported to save space. No significant effect is found to explain the inefficiency scores for the organic technology with the exception of some regional dummies.

In table 2.5, we present ATT for AES and organic farming on the components of PC over the period 2014-2020. Results show a decrease in TE for AES, organic and conventional farms over the period under study. The decrease is of the same order of magnitude for conventional and AES farms, respectively -2.42% and -3.01%. The point estimate of the decrease in TE for farms that adopted the organic technology is more than twice as large as for conventional farms, at 7.59%; however, the ATT is not statistically significant. As previously highlighted when discussing results from table 2.4, the TC over the period is negative for all groups. The technical regress is twice as large for farms adopting the organic technology compared to conventional farms, and the ATT is significant. It shows that in order to generate the same PC as their conventional counterparts, organic farms needed to increase their technical efficiency or their

scale economies faster than if they had remained conventional farms. SC is slightly negative for the conventional technology and positive for both technologies including the voluntary adoption of environmental practices. Farms adopting AES and organic certification increase their scale efficiency on average from 2014 to 2020. However, the ATT analysis shows that the effect is not statistically significant at the 5% level. Finally, PC from 2014 to 2020 for all groups are negative.

The ATTs for PC being non-significant highlight that overall the adoption of AES or organic certification has had no effect on differential farm PC. However, as we utilize identical output price indices for conventional and organic farms, we are likely overestimating organic PC. To our knowledge, there is no previous study on the effect of the adoption of organic farming on PC; hence, it is not possible to compare our results to previous economic literature. Regarding AES contracts, Baráth *et al.* (2020) also found no significant effect of AES adoption on farms' productivity for Slovenian farms. On the contrary, Mennig and Sauer (2020) found that AES contracts increase farms' productivity by 1.2% per year for crop farms. However, it is difficult to compare results from different case studies; Mennig and Sauer (2020)'s dataset is composed of German farms during the previous CAP program (2007-2013) and crop farms are less specialized as they consider farms for which crops share in total sales is greater than 66%. Furthermore, their approach failed to take into account that technologies could differ between AES and conventional farms. In the results presented so far, we analyzed agricultural productivity and efficiency in relation to each farm's own technology. To further compare farms using different technologies against the sector as a whole, a metafrontier is considered.

Table 2.4. Maximum likelihood estimation estimates of the stochastic frontier model for conventional, AES and organic farms

Variables	Parameters	Coefficients (std. err.)		
		Conventional	AES	Organic
<i>Stochastic frontier</i>				
Constant	β_0	0.144*** (0.013)	0.192*** (0.030)	0.090*** (0.031)
Ln labor	β_W	0.061*** (0.011)	0.033 (0.026)	0.014 (0.081)
Ln land	β_L	0.374*** (0.018)	0.289*** (0.047)	0.386*** (0.096)
Ln materials	β_M	0.551*** (0.014)	0.524*** (0.033)	0.521*** (0.062)
Ln capital	β_K	0.049*** (0.003)	0.049*** (0.006)	0.063*** (0.013)
(Ln labor) ²	β_{WW}	-0.027 (0.029)	0.054 (0.076)	-0.331 (0.417)
(Ln land) ²	β_{LL}	0.007 (0.111)	-0.067 (0.203)	0.243 (0.495)
(Ln materials) ²	β_{MM}	0.127* (0.072)	-0.191 (0.180)	-0.063 (0.248)
(Ln capital) ²	β_{KK}	0.009*** (0.001)	0.006*** (0.002)	0.007* (0.004)
Ln labor * Ln land	β_{WL}	-0.026 (0.046)	-0.141 (0.096)	-0.337* (0.192)
Ln labor * Ln materials	β_{WM}	-0.030 (0.039)	-0.062 (0.087)	0.099 (0.173)
Ln labor * Ln capital	β_{WK}	0.015*** (0.004)	0.043*** (0.011)	0.091** (0.041)
Ln land * Ln materials	β_{LM}	-0.120 (0.078)	-0.013 (0.155)	-0.163 (0.298)
Ln land * Ln capital	β_{LK}	0.007 (0.008)	-0.037* (0.022)	0.016 (0.061)
Ln materials * Ln capital	β_{MK}	-0.010 (0.007)	0.023 (0.017)	0.011 (0.034)
Time	β_t	-0.015*** (0.002)	-0.014*** (0.004)	-0.030*** (0.008)
Ln labor * time	β_{Wt}	0.003 (0.005)	-0.003 (0.010)	-0.025 (0.021)
Ln land * time	β_{Lt}	-0.015* (0.008)	0.019 (0.020)	-0.034 (0.031)
Ln materials * time	β_{Mt}	0.018*** (0.007)	0.003 (0.016)	0.068 (0.023)
Ln capital * time	β_{Kt}	0.002*** (0.001)	0.000 (0.002)	0.001 (0.004)
<i>Inefficiency model</i>				
Constant	δ_0	-0.559*** (0.376)	0.371* (0.190)	0.231 (3.068)
Dummies region	δ_1	yes	yes	yes
Employees share	δ_2	0.416*** (0.126)	-0.467 (0.560)	1.793 (4.141)
Land	δ_3	-0.002*** (0.001)	-0.003** (0.001)	-0.014 (0.010)
No irrigation dummy	δ_4	0.283*** (0.103)	0.138 (0.114)	-0.145 (2.286)
$\sigma^2 = \sigma_v^2 + \sigma_u^2$		0.182*** (0.053)	0.110*** (0.033)	1.048* (0.576)
$\gamma = \sigma_u^2 / (\sigma_v^2 + \sigma_u^2)$		0.888*** (0.029)	0.855*** (0.040)	0.986*** (0.009)
Log-likelihood		784.755	197.883	43.201
# of observations		3,558	651	215
% of observation respecting monotonicity		94.52%	71.12%	66.51%

*, **, *** indicate significance at the 10%, 5% and 1% levels, respectively.

Table 2.5. Average treatment effect on the treated for AES and organic farming on the components of productivity change from 2014-2020

Variables	Treated group <i>mean (s.d.)</i>	Control group: conventional farms <i>mean (s.d.)</i>	Treatment effects: <i>ATT</i>
<i>Treated group: AES farms</i>			
TEC (%)	-3.01 (12.59)	-2.42 (11.90)	-0.59
TC (%)	-1.38 (0.71)	-1.46 (0.71)	0.08
SC (%)	1.02 (6.58)	-0.18 (1.95)	1.20***
PC (%)	-3.37 (14.59)	-4.06 (12.11)	0.69
<i>Treated group: organic farms</i>			
TEC (%)	-7.59 (24.45)	-2.42 (11.90)	5.17
TC (%)	-3.10 (1.97)	-1.46 (0.71)	-1.64***
SC (%)	5.96 (40.25)	-0.18 (1.95)	6.14
PC (%)	-4.72 (49.63)	-4.06 (12.11)	-0.66

*TEC – technical efficiency change; TC – technical change; SC – scale change; PC – productivity change. Wilcoxon rank-sum tests are performed; *, **, *** indicate significance at the 10%, 5% and 1% levels, respectively.*

Results of the metafrontier estimation are presented in Table 2.6. The variance of the inefficiency term representing 98% of the total variance supports the implementation of an SF model to estimate the metafrontier. Regarding the inefficiency model, farms with higher crop diversity (larger Herfindahl-Hirschman Index) and higher AES subsidies per hectare operate on average under a lower production frontier. Regarding AES subsidies, this is not surprising because input restriction and environmental practices implementation stringency increase as AES subsidies per hectare grow. With regard to crop diversity, the effect is not clear a priori. On the one hand, low diversity can lead to gains from specialization and achieving economies of scale. On the other hand, crop diversity can generate economies of scope, as the agronomic literature highlights positive effects particularly in pest management and nutrient management such as nitrogen. Crop diversity is even more important for organic farms as chemical inputs are prohibited. Our results highlight that the negative effects of diversification outweigh the positive ones.

Table 2.7 presents ATT on MTEC over the period 2014-2020 for AES and organic farming. MTEC represents farms' TE with respect to the metafrontier. Results highlight a negative causal effect of 11.55% on MTEC resulting from the adoption of organic certification. It is interesting to note that this estimate is within the range of the agronomic literature studying the effect of organic practices on crop yields (-8% to -25%) (de Ponti *et al.*, 2012; Seufert *et al.*, 2012; Reganold and Wachter, 2016). As previously shown in Table 2.5, adopting organic practices

does not significantly affect farms' TE with respect to their own frontier. The loss of efficiency in organic farms is explained by the deviation of their production frontier from the metafrontier: the ATT on the TGR is -7.36%. These results are complementary to the existing literature on organic certification and efficiency. They highlight that the adoption of organic certification leads to a deviation from the production frontier compared to the metafrontier. Due to the constraints organic farms face in terms of input restriction and environmental practices implementation, it is not surprising that they operate under a lower production frontier. However, organic farms are generally efficient relative to their own technology. Yet, our results might slightly underestimate the effect of adopting organic practices on farm efficiency, as we deflated monetary values with identical output price indices for conventional and organic farms.

Regarding AES, results show no significant effect of the adoption on farms' efficiency, neither in terms of efficiency relative to their own production frontier nor relative to the metafrontier. As discussed in section 2, there are a variety of AES contracts, which are more or less stringent and apply to a more or less significant portion of the farm. Thus, depending on the AES contracts and the level of commitment, their effects on farm efficiency can be heterogeneous. Unfortunately, our database does not allow us to differentiate among AES contracts. Previous studies encountered the same methodological issue (Baráth *et al.*, 2020; Mennig and Sauer, 2020; Dakpo *et al.*, 2022). AES subsidies per hectare capture farms' AES engagement either by contracting on a large part of farmland and/or by choosing a stringent contract as subsidies increase with environmental requirements. Despite the limitations of our database, we attempt to explore the heterogeneity of AES contracts by considering two subgroups based on whether their AES subsidies are below or above 40€/ha (the average value perceived within the sample). Results are presented in Table 2.8. Farms receiving 40€/ha or more in AES subsidies experience a larger decrease in TEC and MTEC over the study period. However, the ATTs are not significantly different from zero. In summary, no causal effect of the adoption of differential AES contracts on efficiency is found.

Our results highlight a different effect of the two types of environmental contracts on farms' efficiency. While the adoption of an AES contract has no effect, the adoption of organic farming drastically reduces farms' efficiency by 11.55% between 2014 and 2020. This observation can be explained by several factors. AES contracts requirements are lower than the organic requirements. AES contracts can concern only some plots of the farm as opposed to organic certification, which requires redesigning the production system. In addition, this result can be explained by the AES design itself. AES have been criticized in the literature because of

windfall effects: subsidizing practices that would have been adopted even in the absence of the subsidies (Chabé-Ferret and Subervie, 2013). In our study, we cannot control whether the adoption of AES contracts coincides with the adoption of the practices required by the contracts. Farmers may have implemented the practices before the adoption of the AES contract, taking advantage of the windfall offered by the subsidies to increase their income. This is unlikely to be the case for organic farming, because the adoption of organic practices is not profitable in the absence of market price premiums paid by consumers.

Table 2.6. Maximum likelihood estimation estimates of the metafrontier model

Variables	Parameters	Coefficients (std. err.)
<i>Stochastic frontier</i>		
Constant	β_0	0.163*** (0.001)
Ln labor	β_W	0.058*** (0.002)
Ln land	β_L	0.370*** (0.003)
Ln materials	β_M	0.548*** (0.003)
Ln capital	β_K	0.049*** (0.001)
(Ln labor) ²	β_{WW}	-0.031*** (0.007)
(Ln land) ²	β_{LL}	0.040** (0.019)
(Ln materials) ²	β_{MM}	0.109*** (0.018)
(Ln capital) ²	β_{KK}	0.009*** (0.000)
Ln labor * Ln land	β_{WL}	-0.033*** (0.010)
Ln labor * Ln materials	β_{WM}	-0.023*** (0.008)
Ln labor * Ln capital	β_{WK}	0.015*** (0.001)
Ln land * Ln materials	β_{LM}	-0.135*** (0.015)
Ln land * Ln capital	β_{LK}	-0.002 (0.002)
Ln materials * Ln capital	β_{MK}	-0.004** (0.002)
Time	β_t	-0.015*** (0.000)
Ln labor * time	β_{Wt}	0.000 (0.001)
Ln land * time	β_{Lt}	-0.011*** (0.002)
Ln materials * time	β_{Mt}	0.016*** (0.001)
Ln capital * time	β_{Kt}	0.002*** (0.000)
<i>Inefficiency model</i>		
Constant	δ_0	-3.840*** (0.210)
Herfindahl-Hirschman Index	δ_5	3.226*** (0.177)
AES subsidies / ha	δ_6	0.003*** (0.000)
$\sigma^2 = \sigma_v^2 + \sigma_u^2$		0.020*** (0.001)
$\gamma = \sigma_u^2 / (\sigma_v^2 + \sigma_u^2)$		0.979*** (0.001)
Log-likelihood		9,545.840
# of observations		4,424
% of observation respecting monotonicity		94.10%

*, **, *** indicate significance at the 10%, 5% and 1% levels, respectively.

Table 2.7. Average treatment effect on the treated for AES and organic farming on efficiency from 2014-2020

Variables	Treated group <i>mean (s.d.)</i>	Control group: conventional farms <i>mean (s.d.)</i>	Treatment effects: <i>ATT</i>
<i>Treated group: AES farms</i>			
TEC (%)	-3.01 (12.59)	-2.42 (11.90)	-0.59
TGR (%)	0.34 (3.36)	-0.03 (0.49)	0.37
MTEC (%)	-2.78 (12.25)	-2.44 (11.93)	-0.34
<i>Treated group: organic farms</i>			
TEC (%)	-7.59 (24.45)	-2.42 (11.90)	-5.17
TGR (%)	-7.39 (7.20)	-0.03 (0.49)	-7.36***
MTEC (%)	-13.99 (23.63)	-2.44 (11.93)	-11.55***

TEC – technical efficiency change; TGR – technology gap ratio; MTEC – technical efficiency change with respect to metafrontier.

*Wilcoxon rank-sum tests are performed; *, **, *** indicate significance at the 10%, 5% and 1% levels, respectively.*

Table 2.8. Average treatment effect on the treated for AES sub-groups farms on efficiency from 2014-2020

Variables	Treated group <i>mean (s.d.)</i>	Control group: conventional farms <i>mean (s.d.)</i>	Treatment effects: <i>ATT</i>
<i>Treated group: AES farms</i>			
TEC (%)			
<i>AES subsidies/ha</i> \geq 40 (n=37)	-4.70 (9.64)	-2.42 (11.90)	-2.28
<i>AES subsidies/ha</i> < 40 (n=65)	-2.05 (13.98)	-2.42 (11.90)	0.37
TGR (%)			
<i>AES subsidies/ha</i> \geq 40 (n=37)	0.10 (2.13)	-0.03 (0.49)	0.13
<i>AES subsidies/ha</i> < 40 (n=65)	0.48 (3.90)	-0.03 (0.49)	0.51
MTEC (%)			
<i>AES subsidies/ha</i> \geq 40 (n=37)	-4.63 (9.68)	-2.44 (11.93)	-2.19
<i>AES subsidies/ha</i> < 40 (n=65)	-1.73 (13.46)	-2.44 (11.93)	0.71

TEC – technical efficiency change; TGR – technology gap ratio; MTEC – technical efficiency change with respect to metafrontier.

*Wilcoxon rank-sum tests are performed; *, **, *** indicate significance at the 10%, 5% and 1% levels, respectively.*

2.6. Conclusion

Evaluating the effect of AES and organic contracts on farms' productivity and efficiency is important from a policy point of view, especially in a context where the CAP is required to achieve a variety of objectives, both economic and environmental. We found no effect of the adoption of AES contracts. From a public policy point of view, this finding could be encouraging as it promotes the adoption of environmental practices without affecting negatively the economic objectives of the CAP. However, this finding should be nuanced as previous studies highlight that AES suffer from some drawbacks (Uthes and Matzdorf, 2013; Dupraz and Guyomard, 2019). While AES are usually effective, they can be very expensive in light of the environmental results achieved (Batáry *et al.*, 2015). It is partly explained by the windfall effect captured by the farmers (Chabé-Ferret and Subervie, 2013). Given the variety of AES contracts, it would be important for future research to conduct this kind of analysis by clearly identifying the type of AES contracted in order to estimate their respective impacts on farm efficiency. This requires access to databases with the relevant information and a sufficiently large number of contract holders per AES to conduct a statistical analysis. This is particularly relevant in the context of the implementation of the new instrument of the 2023-2027 CAP, the eco-schemes. They are funded by the first pillar of the CAP, but their adoption is voluntary, similar to AES. The French eco-schemes incorporate requirements from the system AES with lower stringency and are structured in a similar manner, involving commitments for the entire farm.

The adoption of organic farming appears to have reduced farms' efficiency by 11.55% over the period 2014-2020. This results from the fact that organic farms operate under a lower production frontier than conventional farms. Our results show that organic farms are efficient regarding their own production frontier, and that the efficiency loss is due to the switch from conventional to organic production systems. It is important to consider this in perspective with the objectives of the Green Deal, whose goal is to convert 25% of EU agricultural land into organic farming by 2030. An important decline in farms' productivity could raise questions regarding food security, farmers' income, and competitiveness of the EU agricultural sector. In addition, if the instruments used to achieve the Farm-to-Fork objectives lead to a reduction in production, there is a possibility of leakage effects occurring in regions outside the EU (Arvanitopoulos *et al.*, 2021; Henning and Witzke, 2021; Wesseler, 2022).

In this article, we assessed the impact of adopting AES and organic contract on farms' technical efficiency. It must be noted that while the use of inputs like pesticides and fertilizers may increase crop yields, it can also result in bad outputs such as biodiversity decline and nitrogen leaching. However, due to the lack of data, we were not able to take into account the production of bad outputs. A growing body of literature focuses on developing methods to account for the production of bad outputs and thus estimate the environmental efficiency of farms (Dakpo *et al.*, 2016). To complement this study, it would be valuable to evaluate the effect of adopting AES and organic contracts on farms' environmental efficiency. Implementing these methodologies requires data on the production of negative outputs; otherwise, strong and

possibly unrealistic assumptions must be made (Dakpo and Lansink, 2019; Ait Sidhoum *et al.*, 2020; Ait Sidhoum *et al.*, 2023).

For future research on AES and organic contracts, it would also be worthwhile to study the effect of the timing of adoption on farms' productivity. It would be interesting to examine the evolution of productivity for farms that adopted an environmental contract over a longer period to determine whether there is a learning effect over time that allows them to reach efficiency levels closer to those before adoption.

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Chapter 3. The technical and economic effects of biodiversity standards on wheat production

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3.1. Introduction

Biodiversity preservation is essential for crop production; 75% of the world's food crops need animal pollination. Furthermore, an additional ecosystem service provided by biodiversity is natural biological pest control (IPBES, 2019). However, the Intergovernmental science-policy Platform on Biodiversity and Ecosystem Services (IPBES) report highlights that approximately one million animal and plant species are threatened with extinction (IPBES, 2019), mainly because of agriculture and the overexploitation¹ of wild species (Maxwell *et al.*, 2016; Tilman *et al.*, 2017; IPBES, 2019). Intensive agricultural practices have a negative impact on biodiversity through various channels. One channel is the destruction of species habitats by converting them into agricultural land, another is habitat homogenization through increased single-crop farming and the removal of hedgerows (Benton *et al.*, 2003; IPBES, 2019; Sánchez-Bayo and Wyckhuys, 2019; Raven and Wagner, 2021). Moreover, conventional agricultural practices rely on the intensive use of chemical inputs (pesticides and fertilisers) and on tillage that are harmful to biodiversity (Hautier *et al.*, 2009; Geiger *et al.*, 2010; Beketov *et al.*, 2013; Arslan, 2018; Sánchez-Bayo and Wyckhuys, 2019).

The increased awareness of the harmful effects of agriculture on biodiversity can be illustrated by the ambitious objectives set by the Farm to Fork Strategy (European Commission, 2020), part of the European Green Deal. The goal is to reduce by 2030 the use and risk of chemical pesticides at the European level by 50%. Acknowledging that the current Sustainable Use of Pesticides Directive² is not sufficiently binding and is unevenly implemented, thus hindering the attainment of this objective, the European Commission proposes to convert the Directive into a Regulation³ directly applicable in all Member States. Besides the European initiatives, several public and private instruments may be used to prevent biodiversity loss, among which are environmental standards and labels. Environmental labels provide information to consumers about the environmental practices implemented by farmers following standard requirements and that cannot be observed directly by consumers. Consumers are becoming increasingly interested in environmental labels. The European Commission conducted a survey in 2014 that revealed that 75% of Europeans are "willing to buy environmentally friendly products, even if

¹ Species are overexploited when harvesting rates cannot be compensated for by reproduction or regrowth.

² Directive 2009/128/EC of the European Parliament and of the Council of 21 October 2009 establishing a framework for Community action to achieve the sustainable use of pesticides (OJ L 309, 24.11.2009, p. 71)

³ Proposal 2022/0196 (COD) of the European Commission of 22 June 2022 for a Regulation of the European Parliament and of the Council on the sustainable use of plant protection products and amending Regulation (EU) 2021/2115

it costs a little more to do so" (European Commission, 2014). Sessego and Hébel (2019) found that, in 2018, 70% of French people had purchased at least one product with the certified organic label in the previous six months, whereas in 1998 only 44% of them had done so. The use of environmental labels is increasing worldwide; for instance, the Ecolabel Index (2021) identified 455 environmental labels in 199 countries and 25 industry sectors. In the agricultural sector, public and private organisations have developed numerous environmental standards. As far as the public sector is concerned, the organic standard was recognised in 1981 by the French government and harmonised at the European level in 1992. Since 2012, the French Ministry of Agriculture has supported a second standard, the French *High Environmental Value* ('Haute Valeur Environnementale'). This standard is less binding than the organic one, and aims to assess farm environmental performance using four criteria: biodiversity preservation, crop protection management, fertilisation management, and irrigation management. In 2020, through the Farm to Fork Strategy the European Commission aims to create a sustainable label and to harmonise voluntary green initiatives (European Commission, 2020). Private organisations (firms and Non-Governmental Organisations) have also developed their own environmental standards, such as the Marine Stewardship Council in 1996 and Bee Friendly in 2012, to respond to consumer demand for environmentally-friendly products (Saitone and Sexton, 2017). Such standards allow farmers to differentiate with labels their products in the market or to improve market access (Ambec and Lanoie, 2008). Introducing environmental standards in agricultural production affects the structure and the organisation of supply chains. Compliance and monitoring of standards require tighter vertical coordination along the supply chain (Beghin *et al.*, 2015). It is also a way to guarantee farmers a certain price in a food chain that is highly concentrated and where farmers request fair prices and better competition regulations (Swinnen *et al.*, 2021). The wild development of private and public agri-food standards impacts international trade between countries, however the precise effects on trade remain ambiguous (Drogué and DeMaria, 2012; Beghin *et al.*, 2015; Curzi *et al.*, 2018; Fiankor *et al.*, 2019; Santeramo and Lamonaca, 2019; Fiankor *et al.*, 2021).

In the literature studying farmers' choices in adopting an environmental standard, a large body of work has focused on farmers' preferences between adopting an organic standard or remaining under conventional practices (for a review see Dessart *et al.* (2019)). In contrast, the literature is scarce on cases where a variety of environmental standards is offered. Our articles contributes to this literature, specifically in the case of French wheat production, as we compare farmers' choices between two standards aiming at favoring biodiversity: a more stringent and

a less stringent standard. While both these environmental standards require the presence of species habitats on farm plots such as bird perches, hedges, field margins and fallow land dedicated to nectar source plants, the more stringent standard also bans the most toxic pesticides. Wheat produced according to either of the two environmental standards under consideration in this study, is exclusively aimed at the French market and is not exported. Farmers engaged in these standards receive a yearly base price, with a penalty-bonus system linked to quality and a premium linked to the stringency of the environmental standard.

In this article we assess the effects of adopting the most stringent environmental standards in terms of wheat yield and wheat quality (technical effects) and price received (economic effect). The links between the adoption of environmental practices on the one hand, and yield and economic return on the other, has been explored widely in developing countries. Most of the studies show a positive relationship. Di Falco *et al.* (2011) found that farmers who adopted new varieties, soil conservation strategies and tree planting to cope with climate change in Ethiopia obtained higher yields. Abdulai and Huffman (2014) found similar results in Ghana, where they showed that the adoption of soil and water conservation technology increased rice yields and net returns. Kleemann and Abdulai (2013) showed a positive relationship between the intensity of the use of agro-ecological practices and return on investment for pineapple farmers in Ghana. Another part of the literature aimed at understanding the effect of sustainable agricultural standards on socio-economic and environmental indicators in developing countries as well as their effect on the agri-food supply-chain. Literature reviews highlight mixed evidence and context-dependent results (Oya *et al.*, 2018; Meemken *et al.*, 2021; Traldi, 2021). However, the adoption of environmental practices in developing countries is triggered by a diverse set of drivers, such as adaptation to climate change and food security, which differs from that in developed countries where economic incentives play a role. The effects of the adoption of sustainable standards are therefore likely to be different.

The agronomic literature has widely studied the effect on crop yield of the adoption of the organic standard (de Ponti *et al.*, 2012; Seufert *et al.*, 2012; Ponisio *et al.*, 2015; Reganold and Wachter, 2016). Studies have generally identified a negative effect of the adoption of organic practices on yield. In contrast, no consensus has arisen in the economic literature on the relationship between the adoption of the organic standard and technical-economic performance. Most studies have shown that technical efficiency is higher in cases of organic farming as opposed to non-organic farming (Tzouvelekas *et al.*, 2001; Tzouvelekas *et al.*, 2002; Oude Lansink, 2002; Tiedemann and Latacz-Lohmann, 2013; Grovermann *et al.*, 2021). However,

some studies have identified a negative effect of organic certification on technical efficiency (Sipiläinen and Oude Lansink, 2005; Kumbhakar *et al.*, 2009; Serra and Goodwin, 2009), while others did not indicate a significant effect (Mayen *et al.*, 2010; Sauer, 2010; Grovermann *et al.*, 2021). Another strand of literature observes that biodiversity could be considered as a productive ecosystem service (Di Falco, 2012; Bareille and Letort, 2018; Bareille *et al.*, 2020). However, despite the clearly positive link between biodiversity and crop yield (Binder *et al.*, 2018; Garibaldi *et al.*, 2016; Dainese *et al.*, 2019), results from studies evaluating the effect of conservation measures suggested that biodiversity often fails to improve crop yield (Begg *et al.*, 2017).

Our analysis differs from previous studies for several reasons. While most studies examined the adoption of new practices and input use strategies at the farm level, we conduct our empirical analysis at the plot level. This enables the possibility for farmers to implement several environmental standards on their farms on different plots to be taken into account. In contrast to other studies, we do not compare plots under an environmental standard versus those without environmental standard. We consider two environmental standards, one less stringent and one more stringent. Contrary to the organic standard that modifies the whole farming system, the two environmental standards considered here only affect practices on plots and can be considered as intermediate environmental standards. From a public policy point of view, the latter may be considered useful instruments with potential benefits for the environment, since their adoption rate is higher than that of the (more binding) organic standard. In France, organic certified wheat represented just 2.7% of annual wheat production for human consumption in 2019 (Renault *et al.*, 2020). In comparison, the most stringent standard studied here (later referred to as the *H standard*) accounted for 10% of French annual wheat production for such purposes, while the less stringent standard (later denoted the *L standard*) has been adopted by 4% of French farmers producing wheat. To our knowledge, no study has investigated the role of such intermediate standards on farm's technical and economic outcomes.

The second contribution is that our study complements the literature on the effects of input use on farm outcomes through quality assessment. Most studies have focused on effects on yield and economic results in order to assess input economic value or productivity (Carpentier and Weaver, 1997; Sexton, 2007; Kawasaki and Lichtenberg, 2015; Koussoubé and Nauges, 2017). Only a limited number of papers have taken into account how input use influences product quality, showing that ignoring quality underestimates the economic value of pesticide use (Babcock *et al.*, 1992; Cobourn *et al.*, 2013; Kawasaki and Lichtenberg, 2015). Here, we assess

the effect on wheat quality of input management changes (required by the adoption of the more stringent environmental standard). We specifically consider two quality attributes: test weight and protein content. Both quality attributes are important for wheat processing activities (Larue, 1991). Test weight is a quality attribute for milling activities and protein content is useful for bakers.

Finally, we implement an endogenous switching regression, allowing a counterfactual analysis. Several studies also used an endogenous switching regression to account for the endogeneity of technology adoption when assessing the effect of technology adoption in developing countries (Di Falco *et al.*, 2011; Kleemann and Abdulai, 2013; Abdulai and Huffman, 2014; Di Falco and Veronesi, 2013; Kassie *et al.*, 2015; Abdulai, 2016; Kassie *et al.*, 2018). However, a limited number of endogenous switching regression analyses have been conducted in developed countries. Laple *et al.* (2013) assessed the effect of a public programme on farm profit. More recently, two studies assessed the effect of foreign labour and innovation towards climate variability on firm performance (Antonioli *et al.*, 2021; Auci *et al.*, 2021). With the exception of Auci *et al.* (2021), previous studies only took technology adoption endogeneity into account. By contrast, here we account for two endogeneity issues: one related to the adoption of the most stringent standard; the second to the use of input quantities. When estimating wheat yield, quality and price, inputs may be correlated to the error term as we omit pest infestation measures because of lack of information (Frisvold, 2019). We follow the approach of Murtazashvili and Wooldridge (2016), based on an endogenous switching regression. This enables the endogeneity of the explanatory variables in addition to the selection variable endogeneity to be accounted for.

The rest of the article is organised as follows. Firstly, we describe the data used and discuss summary statistics (section 2). Then we explain our empirical strategy based on the endogenous switching regression method (section 3), and we present and discuss our results (section 4). In the final section, we offer our conclusions (section 5).

3.2. Data

Our empirical study is applied to wheat production in France, which is a major crop production in the country. Wheat represents 54% of total French cereal production and from 2014 to 2018, 5 million hectares on average were cultivated with wheat, representing 17% of French agricultural land. France is the largest producer of wheat in Europe and the fifth largest on a world scale (FranceAgriMer, 2021).

We focus on two specific intermediate environmental standards for which farmers can change practices at the plot level and within a production year. We refer to an environmental standard as intermediate if its requirements are higher than conventional practices but lower than the organic requirements. We exclude from our analysis the organic standard that requires a radical change in farming system and a three-year transition period. The two intermediate environmental standards considered here are: the *L standard* that has lower requirements on biodiversity and only requires the existence of biodiversity habitats (e.g. bird perches or hedges), and 3% of arable land covered with nectar-source plant fallow; the *H standard*, that has higher requirements than the *L standard* because it constrains the use of pesticides. More precisely, most toxic active ingredients are prohibited under the *H standard*, and there is a list of non-recommended active ingredients, which are allowed but the quantity used should be limited. Although the *H standard* requirements do not impose a limit on the total amount of pesticide use, we note that its requirements are in line with the Farm to Fork Strategy's objective to reduce risk of chemical pesticides by binding most toxic pesticides.

Studies in ecology have shown that biodiversity increases in response to conservation measures, such as those requiring habitat diversification and low-input practices (Attwood *et al.*, 2008; Begg *et al.*, 2017; Graham *et al.*, 2018; Albrecht *et al.*, 2021). Thus, when adopting the *L* or *H* standards, farmers modify their agricultural practices in a way that favours biodiversity. However, as explained above, the private consequences for farmers of adopting one or the other standard are not clear. Our level of observation is plots. All of the plots in our database are cultivated with wheat under an environmental standard, either *L* or *H* standard. We will estimate the effect for three outcomes (yield, quality, price) of producing under the *H standard* rather than the *L standard*. The data were collected between 2014 and 2020 by an agricultural cooperative whose substantial share of wheat production is dedicated to agricultural products under different standards. The cooperative offers technical services to their members to encourage them to change their agricultural practices. The agricultural cooperative collects

precise agronomic data on input use and wheat quality for plots. Farmers who choose to adopt standards on their plots receive technical visits from the cooperative's advisors at least four times a year. These visits aim to provide technical advice to farmers and to ensure that they comply with the requirements of the standards' specifications. Farmers who adopt one of the standards are obliged to inform the cooperative of all practices on plots where they adopted a standard (e.g. date of sowing; date, quantity and product used for each pesticide and fertiliser application; date and type of tillage etc.). Farmers can either provide this information via a web application linked to the cooperative database or record the information on monitoring sheets provided by the cooperative. During their visits, the cooperative advisors ensure that the information provided corresponds to the practices implemented. Control is facilitated by the obligation of farmers to purchase crop protection and fertiliser inputs from the cooperative. In addition, the cooperative measures wheat quality systematically and precisely because the price paid to the farmer is calculated with a penalty-bonus system based on quality. However, the cooperative does not collect information on input use for plots under conventional agricultural practices. Farmers who are members of the cooperative can decide for each plot whether they would like to adopt the *L standard*, the *H standard* or neither of them.

Our database includes 8,015 observations at the plot level for the whole period 2014-2020. The database is composed of all the plots cultivated under the *H* or *L standard* within the cooperative. The plots are operated by 278 farms located in the French region Poitou-Charentes. Each year, farms in the sample have, on average, seven plots of wheat cultivated under one of the environmental standards. The 8,015 plot observations are not panel data. Table 3.1 highlights that most plots (64%) are present only one year in the database and about 11% of the plots appear more than twice. This is due to crop rotation, which prevents the production of wheat on the same plot in consecutive years. There are various types of crop rotations, varying in length; e.g. 3-year crop rotation (canola-common wheat-barley), 4-year crop rotation (corn-peas-durum wheat-common wheat), and 5-year crop rotation (corn-common wheat-sunflower-durum wheat-barley) (Chambres d'agriculture, 2020). Our database includes 7 years and is composed of plots cultivated with common wheat. Thus, for short rotations, we can expect to identify them two to three times in the database, however for long rotations they will probably appear only once. Almost two-thirds of the plot observations (65%) are produced under the *H standard*. Some plots, irrespective of the pesticides used on them, are not eligible for the *H standard* because of their intrinsic characteristics, such as being close to a highway. In our sample, 55% of the plots with the *L standard* are eligible to apply the *H standard*. Most plots

(90%) are cultivated by farmers with previous experience of the *H standard*. In addition, the majority of the plots in our dataset (72%) are cultivated by farmers who adopted both the *L* and the *H standard* but on different plots and in different proportions.

Table 3.1. Observation of plots across years in the database

Number of years a specific plot is observed	Number of plots	Percentage of plots
1	3431	64%
2	1367	25%
3	464	9%
4	107	2%
5	6	0.1%
6	0	0%
7	0	0%

The database also includes information about the farms operating the plots, input management, plot characteristics, and technical (i.e. yield and quality attributes) and economic (i.e. wheat price) outcomes. We consider two quality attributes of wheat: test weight and protein content. Wheat price is determined by a set of parameters depending on the quality level. The wheat price formula is based on a yearly base price and includes a bonus-penalty system for quality attributes, and price premiums for the adoption of the environmental standards. While the base price is only known at harvest time, farmers know the values of the bonus-penalty system and the price premiums prior to wheat sowing. As all plots in our sample are cultivated by farmers who are members of the same cooperative, in a given year the latter face the same market environment.

In addition to the plot-level data provided by the agricultural cooperative, we used information on weather conditions from SICLIMA Extraction at a resolution of 8 km². SICLIMA Extraction is a web application developed by the INRAE Agroclim research unit from daily weather information provided by Météo-France (the French national centre for meteorological research). We used the R *meteoRIT* package (Desjeux, 2019) to transfer weather data at a resolution of 8 km² to municipality resolution. Thus, knowing the localisation of each plot in terms of the municipality where it is located, we were able to match plot-level data with municipality-level weather data. We used two weather variables: daily average temperature, and cumulated precipitation over the wheat growing season (10th March to 10th July).

Table 3.2 presents descriptive statistics of the data and a comparison of mean characteristics between plots with the *H standard* and plots with the *L standard*. In our database about one-third of the plots are tilled, which is in line with the French average for wheat plots (Agreste, 2020b). The mineral nitrogenous (N) fertilisation applied is 180 kg N/ha on average, slightly higher than the French average of 164 kg N/ha (Agreste, 2020a). The herbicide treatment frequency index (TFI)⁴ and insecticide TFI are close to the regional average, 1.8 and 0.3, respectively. The fungicide TFI is slightly lower than the regional average (1.5). The average wheat yield per plot reaches approximately 6 tons/ha. As far as the quality attributes are concerned, the test weight is 79.25 kg/hl and the protein content in wheat reaches 12.10% on average. Quality attributes for our sample are, on average, above the French average wheat quality (78.27 kg/hl for test weight and 11.58% for protein content).

Comparing mean characteristics between plots with *H standards* and plots with *L standards*, figures show that the two groups have significantly different agricultural practices and farm characteristics. We note that the plots with the *H standard* are more frequently observed in farms with livestock and are on average bigger. Farmers may have higher benefits from adopting the H standard on larger plots as they can expect higher returns from this adoption. In addition, adoption may imply fixed costs and the latter can be spread across a larger area. More plots with the *H standard* are tilled, and are less likely to have been planted with corn in the previous season compared to plots with the *L standard*. Since most toxic herbicides are prohibited in the *H standard*, on plots where this standard applies farmers rely on agronomic strategies to limit pesticide use, such as tilling (which can destroy weeds) and not planting wheat after corn (thus limiting the use of fungicide to treat Fusarium wilt). We find no significant difference in terms of quality of the chosen variety. French wheat varieties are classified in two categories according to their baking qualities. The variable *high quality varieties* reports this classification. We observe differences in crop protection management at the 1% level of significance, whereas fertilisation management differs only at the 10% level of significance. Herbicide TFI, insecticide TFI and fungicide TFI are higher for plots with the *H standard* than for plots with the *L standard*. We did not expect that plots with the *H standard* would receive a higher quantity of pesticides. However, although the set of rules for the *H standard* implies binding requirements on the applied quantity of moderate toxically active ingredients, it does

⁴ TFI is an indicator widely used by French decision makers for monitoring the use of pesticides in agriculture. It counts the number of reference rates used per hectare during a crop year:

$$TFI = \sum_{pesticides} \frac{\text{applied rate}}{\text{reference rate}} * \frac{\text{area treated}}{\text{plot area}}$$

not limit the total applied quantity. In other words, farmers producing under the *H standard* use less effective active ingredients at a higher rate, because of the ban on the most toxic ingredients that are also the most effective active ingredients. In terms of technical outcomes, we observe similar yield and similar test weight in the two groups. In contrast, protein content is slightly higher for plots with the *H standard*. The price received by farmers by ton of wheat sold to the cooperative is higher for plots with the *H standard*, by €5.65/ha on average.

Table 3.2. Variables definition and descriptive statistics for the plots

Variable	Definition	Full plot sample		Comparison of mean characteristics		
		Mean	Std. dev.	Plots - <i>L standard</i>	Plots - <i>H standard</i>	Significance ¹
Outcome variables						
	<i>TECHNICAL OUTCOMES</i>					
Yield	Yield (tons/ha)	5.96	2.08	5.96	5.96	n.s
Test weight	Test weight (kg/hl)	79.25	2.94	79.21	79.27	n.s
Protein content	Protein rate (%)	12.10	0.96	12.06	12.13	***
	<i>ECONOMIC OUTCOME</i>					
Wheat price	Price paid to farmers (€/ton)	170.62	13.26	166.94	172.59	***
Plot agricultural practices and characteristics						
	<i>FERTILISATION MANAGEMENT</i>					
Mineral N quantity	Mineral nitrogen unity applied (kg/ha)	180.43	36.90	181.19	180.02	*
	<i>CROP PROTECTION MANAGEMENT</i>					
Herbicide TFI	Treatment frequency index for herbicide	1.74	0.79	1.70	1.77	***
Insecticide TFI	Treatment frequency index for insecticide	0.34	0.56	0.27	0.37	***
Fungicide TFI	Treatment frequency index for fungicide	1.36	0.64	1.33	1.38	***
	<i>PLOT MANAGEMENT</i>					
Corn as previous crop	1 if the previous crop was corn, 0 if not	0.34		0.55	0.22	***
Tillage	1 if the plot has been tilled, 0 if not	0.38		0.22	0.47	***
	<i>VARIETY</i>					
High quality varieties	1 if high quality variety, 0 if not	0.89		0.88	0.89	n.s
	<i>PLOT SIZE</i>					
Plot size	Plot size (ha)	5.06	4.85	3.45	5.64	***
Farm characteristics						
Livestock	1 if livestock on farm, 0 if not	0.24		0.17	0.27	***
<i>H standard</i> previous experience	1 if farmers have previous experience with the <i>H standard</i> , 0 if not	0.90		0.86	0.92	***
Weather variables						
Temperature	Daily average temperature (°C)	14.42	0.79	14.33	14.48	***
Precipitation	Cumulated precipitations (mm)	224.94	51.87	223.85	225.55	***
Exclusion variable						
Highway	1 if the plot is located close to a highway, 0 if not	0.08		0.22	0.00	***
Number of observations		8,015		2,789	5,226	

*, **, *** indicate significance at the 10%, 5% and 1% levels, respectively.

¹A Wilcoxon rank-sum test is performed for continuous variables and a chi-square test of independence is performed for categorical variables.

3.3. Empirical strategy

Our objective is to estimate the effect of the adoption of more stringent environmental standard on three technical outcomes (yield, test weight and protein content) and on an economic outcome (wheat price) at the plot level. We consider only plots where farmers choose to adopt an environmental standard. Farmers can decide whether they only want to adopt the less stringent standard, the *L standard*, or whether they prefer to adopt the more stringent standard, the *H standard*. We then estimate the effect of adopting the *H standard* rather than the *L standard*.

Two endogeneity issues arise for the empirical analysis. Firstly, we may encounter the issue of farmers' self-selection of specific plots. Observable and unobservable farmer and plot characteristics might affect the choice of adopting the *H standard* and consequently it might affect the estimation of yield, quality and wheat price. Secondly, another source of endogeneity is linked to omitted variables. When estimating yield, quality and wheat price, we use input quantities (fertiliser and pesticides) as explanatory variables. Inputs may be correlated to the error term as we omit pest infestation measures because of lack of information (Frisvold, 2019).

To deal with the potential endogeneity of the adoption of the *H standard* we implement an endogenous switching regression model (ESR), for three reasons. Firstly, this approach is more robust than a classic instrumental approach due to the forbidden regression problem (Angrist and Pischke, 2008). Secondly, the ESR approach which allows observable and unobservable characteristics to be taken into account, is also more robust than matching methodologies which rely only on observed characteristics (Imbens and Wooldridge, 2009). Thirdly, while a more robust approach would be to compare observations before and after the adoption of the *H standard* as in the difference-in-difference methodology, we cannot use it since we do not have panel data due to crop rotation at the plot level.⁵ The advantage of the ESR method is that it allows us to consider two different technologies, one on plots producing under the *H standard* and another on plots producing under the *L standard*.

To implement the ESR model, we follow the Murtazashvili and Wooldridge (2016) specification. The advantage of this methodology over others (such as Fuglie and Bosch (1995), Di Falco *et al.* (2011), Drukker (2016)) is that it deals with the two sources of endogeneity

⁵ The difference-in-difference methodology is widely used in the literature to estimate the impact of a treatment such as the adoption of new practices or the consequences of the implementation of public policies (Bravo-Ureta *et al.*, 2020; Mennig and Sauer, 2020).

mentioned above: the self-selection issue and that associated with omitted explanatory variables. The ESR approach is a two-stage procedure based on the control function approach. At the first stage of the ESR, we determine the factors which influence the adoption of the *H standard* on a plot, and that refers to the selection equation. We assume that the decision to adopt the *H standard* on plot p depends on the expected net utility of this decision. If the utility derived from the adoption of the *H standard* is greater than that for the decision to adopt the *L standard*, then the *H standard* will be adopted on the plot. We define the latent variable A_p^* that represents the expected net utility on plot p from the adoption of the *H standard* instead of the adoption of the *L standard*. A_p^* is a function of factors which affect the expected net utility of producing under the *H standard*. However, we do not observe the latent variable, A_p^* . We only observe the decision whether the *H standard* is adopted on the plot or not, A_p , which is related to the latent variable A_p^* as follows:

$$A_p = \begin{cases} 1 & \text{if } A_p^* > 0 \\ 0 & \text{otherwise} \end{cases} \quad (1)$$

Thus, the first stage of the ESR relies on a probit model given by:

$$A_p = 1[k + x_p^{exo}\pi_1 + z_p\pi_2 + q_p\pi_3 + u_p > 0], u_p \sim N[0,1] \quad (2)$$

where k represents the constant, x_p^{exo} is a vector including the exogenous variables of the outcome equation (see equation (3) below), z_p is a vector gathering the instruments of the endogenous explanatory variables, and q_p is the vector of the instruments of the selection variables. π_1, π_2 and π_3 are vectors of parameters to be estimated and u_p is the error term.

To instrument the selection variables, we rely on an exclusion variable, q_p that directly affects the selection variable but not the outcome variables (yield, test weight, protein content, and wheat price). As the exclusion variable we use a dummy defining whether or not plots are located close to a highway (*highway*), since a plot close to a highway cannot be eligible for the *H standard* to avoid possible contaminations of wheat grains by the pollutions emitted into the air by vehicles. This constraint shows that, beyond the objective of preserving biodiversity, the *H standard* seeks to reassure consumers on health aspects. Indeed, several studies show that health attributes are major motivating factors for consumers to buy products with environmental standards (see Asioli *et al.* (2017) for a review). The *highway* variable thus affects the probability that a plot is certified under the *H standard* but we can reasonably assume that distance to a highway does not affect the outcome variables (yield, test weight, protein content

or price). Unlike in developing countries, in France the proximity of a plot to a highway does not facilitate access to certain input or output markets. Highway exits are not frequent and therefore proximity to a highway does not indicate that a plot would be better connected to the road network. Furthermore, cooperatives are the main input providers and buyers for French farmers and they ensure equal treatment of their members. Farmers thus have the same market access to inputs and outputs regardless of the geographical location of their plots.

In the second stage of the ESR, we estimate separately the equations of the outcome variables, y_p . The second-stage equation is a linear combination of two technologies:

$$y_p = A_p y_p^1 + (1 - A_p) y_p^0 \quad (3)$$

where y_p^1 and y_p^0 represent the technologies used on the plots producing under the *H standard* and *L standard*, respectively.

The selection bias is tackled by adding the generalised residuals estimated in the first stage ($\widehat{g\hat{r}}_p$). For a detailed description of the model, see Vella and Verbeek (1999) and Murtazashvili and Wooldridge (2016). The second stage is estimated with two-stage least squares (2SLS) using the following equation:

$$y_p = x_p^{exo} \beta_0^{exo} + A_p x_p^{exo} \beta_T^{exo} + x_p^{endo} \beta_0^{endo} + A_p x_p^{endo} \beta_T^{endo} + \rho_0 \widehat{g\hat{r}}_p + \rho_T A_p \widehat{g\hat{r}}_p + a_p \quad (4)$$

$$with \ E(a_p | A_p) = 0$$

where the vectors x_p^{exo} and x_p^{endo} include the exogenous variables and the endogenous explanatory variables, respectively. β_0^{exo} , β_0^{endo} , β_T^{exo} , β_T^{endo} , ρ_0 and ρ_T are vectors of parameters to be estimated. a_p is the error term.

Equation (4) estimates the outcome variable as a linear combination of the two technologies. β_T^{exo} is the difference between the two coefficients of x_p^{exo} or, in other words, the difference between the adopters of the *H standard* (technology 1) and the adopters of the *L standard* (technology 0), thus $\beta_T^{exo} = \beta_1^{exo} - \beta_0^{exo}$. Likewise, $\beta_T^{endo} = \beta_1^{endo} - \beta_0^{endo}$ and $\rho_T = \rho_1 - \rho_0$.

In our specification, the endogenous explanatory variables are the input quantities (mineral N quantity, herbicide TFI, insecticide TFI and fungicide TFI) as we expect them to be correlated with the error term. Previous studies used various instrumental variables to instrument pesticide use, which is a major concern when estimating production function (Frisvold, 2019). In the

same vein as Kawasaki and Lichtenberg (2015), we instrument input quantities by the average quantities used on neighbouring plots. We assume that neighbouring plots of a specific plot are those located in a municipality within a radius of 10 km from the specific plot's municipality. Similar to Kawasaki and Lichtenberg (2015) in our database we do not account for all neighbouring plots since we cover only wheat plots under environmental *L* or *H standards*. Average input quantities used by neighbouring plots are expected to be correlated to input quantities used on the specific plot considered, since neighbouring plots face similar pest infestations. We can reasonably assume that our instruments do not directly affect outcome variables because wheat yield, quality and price depend highly on the plot characteristics, such as soil quality and plot management. Our exogenous variables are: *previous crop* (the crop produced the previous year on the same plot); *tillage*; *high quality varieties*; *plot size*; farm characteristics; and weather conditions. We include *year* dummy variables to take into account annual variability and *small agricultural region* dummy variables as a proxy of soil quality. In our database, we count five small agricultural regions.

Past studies have found that various characteristics of farmers and farms, such as age, education, risk aversion, environmental concern, neighbouring farms' practices, and knowledge affect the adoption of environmental practices or environmental standards (see Knowler and Bradshaw (2007) and Dessart *et al.* (2019) for literature reviews). In our estimations, we take into account only a few of these farm and farmer characteristics (namely, a dummy for the presence of livestock on farm, and a dummy for *H standard* previous experience) due to lack of information in our database. Because of the unbalanced nature of our dataset, we are not able to add farm fixed-effects to our model that uses the Mundlak device as recommended by Murtazashvili and Wooldridge (2016). Indeed, farmers and plots are not observed each year, and averaging variables across different years may not effectively capture the individual characteristics of farms due to varying weather conditions and fluctuating pest pressures. However, unlike other studies, farmers here choose to adopt the *H standard* instead of the *L standard* at the plot level and not at the farm level. A majority of plots (72%) are operated by farmers who choose to adopt both standards on their farm but on different plots. Thus, farmers' characteristics should not have a strong effect on the adoption of the standard on a specific plot, as compared to the effect of plot technical and agronomic characteristics.

A wide range of literature demonstrates the effect of weather on crop yields (Di Falco *et al.*, 2011; Chavas *et al.*, 2019; Ramsey, 2020; Miller *et al.*, 2021; Wing *et al.*, 2021). Some studies also show that weather affects crop quality (Kawasaki and Uchida, 2016; Lyman *et al.*, 2013).

Therefore, it is important to control for weather conditions when estimating wheat yield and quality. However, this is challenging as some weather effects are cumulative whereas others differ depending on timing and duration (Chavas *et al.*, 2019), and weather influences on yield depending on the crop stage of development (Ben-Ari *et al.*, 2018). In the economic literature, there are no standardised indicators to take into account weather effects. The most commonly used indicators are cumulative precipitation and temperature (mean, degree-days or thresholds). Some studies have used indicators across the year (Chavas *et al.*, 2019), across the growing season (Deschênes and Greenstone, 2007; Ramsey, 2020; Miller *et al.*, 2021; Wing *et al.*, 2021), at a seasonal level (Van Passel *et al.*, 2017; Bozzola *et al.*, 2018) and at a crop-stage level (Kawasaki and Uchida, 2016). We use the most common indicators in the literature, namely average temperature and cumulative precipitation across the growing season.

Separating equation (4) into the two technologies allows us to compute the expected outcome variables for plots with the *H standard* $E(y_p^1|A = 1)$, and to determine the expected outcome variables in the counterfactual hypothetical case where the plots with the *H standard* adopt the *L standard*, $E(y_p^0|A = 1)$. The conditional expectations are specified as follows:

$$E(y_p^1|A = 1) = x_p^{exo} \beta_1^{exo} + x_p^{endo} \beta_1^{endo} + \rho_1 \widehat{g\tau}_p \quad (5a)$$

$$E(y_p^0|A = 1) = x_p^{exo} \beta_0^{exo} + x_p^{endo} \beta_0^{endo} + \rho_0 \widehat{g\tau}_p \quad (5b)$$

In line with Heckman *et al.* (2001), we compute the effect of the treatment, which is adopting the *H standard*, on the treated plots (TT) (plots under the *H standard*). In other words, TT represents the effect of the adoption of the *H standard* on the outcome variables for plots that actually adopt the *H standard*. TT can be obtained by combining equations (5a) and (5b) as follows:

$$\begin{aligned} TT &= E(y_p^1|A = 1) - E(y_p^0|A = 1) \\ &= x_p^{exo} (\beta_1^{exo} - \beta_0^{exo}) + x_p^{endo} (\beta_1^{endo} - \beta_0^{endo}) + (\rho_1 - \rho_0) \widehat{g\tau}_p \end{aligned} \quad (6)$$

3.4. Results

Estimation of the ESR model was implemented in Stata following the procedure described by Murtazashvili and Wooldridge (2016). The first step, namely the probit model, was run with the command *probit* with standard errors clustered at the farm level. The calculation of

generalised residuals is performed with the command *predict var, score*. The second step was estimated by 2SLS with the command *ivregress*, with bootstrapped standard errors.

3.4.1. Explaining the adoption of the H standard on a plot

The results of the first stage of the ESR model are presented in Table 3.3. The probability of adopting the *H standard* on a plot depends on agricultural practices. More precisely, the probability of adopting the *H standard* is higher if the plot is tilled compared to not tilled, and lower if corn is the previous crop grown compared to other previous crops. Since most toxic (and thus most effective) herbicides are prohibited in the *H standard*, farmers tend to rely more on tillage to control weeds on the plots operated under the *H standard*. The plots where corn was the previously-grown crop are more sensitive to Fusarium wilt, thus farmers may choose not to adopt the *H standard* on these plots as they are limited in fungicide use in terms of active ingredients and quantity. *Plot size* has a positive effect on probability of adopting the *H standard*. This is in line with expectations that farmers may see higher benefits in adopting the *H standard* on larger plots as they expect higher returns on their investment. However, ecologists have shown that reducing plot size can favour biodiversity (Sirami *et al.*, 2019; Martin *et al.*, 2020). This result highlights a limit of the *H standard* as there are higher benefits for farmers to adopt this standard on larger plots. Moreover, farmers' past experience with the *H standard* increases the probability of adopting the *H standard* on a plot. This suggests that the adoption of new practices may imply entry costs for farmers; farmers who already know the agricultural practices used to obtain the *H standard* are more willing to further adopt it on their plots. Finally, we show that the exclusion variable explains the probability of a plot adopting the *H standard*. More precisely, being close to a highway has a negative effect, which conforms to intuition, as plots close to a highway are not eligible for the *H standard*.

To check the relevance of using *highway* as an exclusion variable, we implement falsification tests on each outcome variable, following the ESR literature (Di Falco *et al.*, 2011; Di Falco and Veronesi, 2013; Antonioli *et al.*, 2021; Auci *et al.*, 2021). As previously discussed, the instrument variable *highway* is a significant driver of the probability of adopting the *H standard*. In addition, we perform a Wald test, presented in Table 3.3, confirming this result ($\chi^2(1)=183.87^{***}$). Falsification tests are presented in the Appendix, Table 3A.1. Wald tests implemented on the instrumental variable reveal that the latter does not affect technical outcomes (yield: $\chi^2(1)=2.55$; test weight: $\chi^2(1)=2.28$; protein content: $\chi^2(1)=1.95$). This result

supports our choice of selection instruments. However, the Wald test performed on instrumental variables for the outcome variable price is significant ($\chi^2(1)=31.28^{***}$), since being close to a highway is statistically significant in the estimation of wheat price for plots that did not adopt the *H standard*.

Table 3.3. First-stage coefficient estimation – selection equation

Dependent variable	<i>H standard</i> adoption	
	Coef.	Robust Std. Err.
Corn as previous crop dummy	-1.550***	0.101
Tillage dummy	1.431***	0.117
High quality varieties dummy	0.121	0.091
Plot size	0.053***	
H standard experience dummy	0.599***	0.146
Livestock dummy	0.143	0.141
Temperature	0.174	0.618
Precipitation	-0.003	0.035
Temperature * Precipitation	0.001	0.002
Mineral N quantity - neighbouring plots	-0.007*	0.004
Herbicide TFI - neighbouring plots	-0.021	0.267
Insecticide TFI - neighbouring plots	0.718**	0.295
Fungicide TFI - neighbouring plots	0.195	0.271
Highway dummy	-3.371***	0.249
Constant	-3.860	9.160
<i>Pseudo R</i> ²	0.412	
<i>Wald test</i> $\chi^2(24)$	604.56***	
<i>Wald test on exclusion restriction</i> $\chi^2(1)$	183.87***	
Number of observations	8,015	

*, **, *** indicate significance at the 10%, 5% and 1% levels, respectively.

Note: We include the year's dummy variables and small agricultural region dummy variables but do not show the results. Standard errors are clustered at the farm level.

We assume that farmers are risk-neutral toward the adoption of the *H standard* on their plots compared to the *L standard*. There exists a large body of literature exploring the role of risk aversion in individuals' decisions and risk management (Arrow, 1964; Akerlof, 1970; Pratt, 1978; Antle, 1983). Dessart *et al.* (2019) identified risk tolerance as a behavioural factor positively affecting the adoption of sustainable farming practices. Gardebroek (2006) and Serra *et al.* (2008a) showed that organic farmers are less risk averse than conventional ones. Our risk-neutral assumption is justified for several reasons. Firstly, the adoption of the *H standard* affects

pesticide use as it prohibits the most toxic pesticides, but there is no limitation on total quantity use. Thus, farmers have other alternatives for controlling pests on their plots. Secondly, there is no consensus in the literature as to whether pesticides are considered to be risk decreasing. Some studies found that pesticides are an input-reducing production risk (Di Falco and Chavas, 2006; Koundouri *et al.*, 2009; Antle, 2010; Gong *et al.*, 2016) whereas others found them to be risk-increasing for output (Gotsch and Regev, 1996; Serra, 2006; Serra *et al.*, 2008b; Antle, 2010). Furthermore, studies that tended to quantify the impact of risk aversion on pesticide quantity mainly showed that the effect is small (Carpentier, 1995; Pannell *et al.*, 2000; Bontemps *et al.*, 2021). Using an expected utility model, Bontemps *et al.* (2021) estimated that risk aversion is accountable for less than 4% of the optimal pesticide expenditures.

3.4.2. Effect of the H standard adoption on technical outcomes – yield and quality

We present the results of the second stage of the ESR model for technical outcome variables (yield and quality attributes, namely test weight and protein content) in Table 3.4. Columns (1), (2), and (3) show the results of the outcome equations for yield, test weight and protein content, respectively. As explained in the empirical strategy section, we present the estimates of the outcome variables as a linear combination of the two technologies. It should be stressed that, in this specification, the coefficients for the adopters of the *H standard* (β_1) are the sum of the estimated coefficients for the adopters of the *L standard* (β_0) and the estimated coefficients of the variables with *H standard* interaction terms ($\beta_1 = \gamma_T + \beta_0$). In other words, in Table 3.4, the effect of a specific variable e.g. *mineral N quantity*, for plots under L standard is provided by the estimated coefficient of the variable *mineral N quantity* alone; while the effect of *mineral N quantity* for plots under *H standard* is provided by the estimated coefficient of the variable *mineral N quantity* plus the estimated coefficient of the interacting term *mineral N quantity* * *H standard*.

We show that a selection bias exists in the adoption of the *H standard* on a plot regarding test weight, but no selection bias is found for yield and protein content. For the yield and protein content estimation, both estimated coefficients of the generalised residuals terms, ρ_1 and ρ_0 , are not significantly different from zero. These two coefficients measure the correlation between the error term of the selection equation and the error term of the outcome equation for plots with the *L standard* (ρ_0) and plots with the *H standard* (ρ_1). For test weight, ρ_1 is negative whereas ρ_0 is positive at 10% of significance ($\rho_1 = -0.487^*$ and $\rho_0 = 0.260^*$). It indicates a

positive selection bias for plots with the *H standard* and a negative selection bias for plots with the *L standard*. It suggests that plots that get higher than average test weight are more likely to adopt the *H standard* whereas plots with lower average test weight are more likely to adopt the *L standard*. Furthermore, the Anderson-Rubin test on our instrumental variables validates our choice to instrument input quantities by average input quantities used by neighbouring plots.

Table 3.4 shows that the constant of the model is not significant in all models. This may arise from the fact that farmer-specific effects cannot be included due to the non-panel data structure of our data. Results show that the coefficient of the *H standard* adoption variable (*H standard dummy*) is statistically significant for quality attributes and yield, meaning that the intercepts of the two technologies (technology under *H standard* and technology under *L standard*) differ. Results also show that agricultural practices have an influence on yield and quality attributes, but their effect differs between the two technologies; that is to say, depending on whether the plot is under *H standard* or *L standard*. For example, tillage has an opposite effect on yield between the *H standard* and the *L standard*: in column (1) the coefficient for *tillage* is 0.252 implying that the effect for *L standard* plots is positive; while the sum of this coefficient and of the coefficient for the interacting variable *tillage * H standard* is negative ($=0.252-0.557$) implying that the effect of tillage for the *H standard* plot is negative. A similar reading of the coefficients in Table 3.4 show that, contrary to yield and test weight, input management barely affects protein content. The result indicating mineral N quantity only slightly affects protein content for plots with the *H standard* (and does not affect protein content for plots with the *L standard*), may seem counterintuitive. However, protein content mainly depends on the last application of mineral N and not on the total quantity applied and it is mainly affected by weather conditions. The results show no evidence of an effect of weather conditions on yield. This result differs from previous studies showing that weather conditions do affect yield (Di Falco *et al.*, 2011; Chavas *et al.*, 2019; Ramsey, 2020; Miller *et al.*, 2021; Wing *et al.*, 2021). However, in our analysis, we only consider a seven-year period and we control in part for localisation with the dummies for small agricultural regions. This implies that there is only a slight variation in weather conditions among the considered plots, which may explain why we do not detect a weather effect on yield.

Table 3.5 presents the average outcomes for yield, test weight and protein content, under actual and counterfactual conditions. The last column reports the treatment effects of the adoption of the *H standard* on the treated (TT) for plots with the *H standard*. Our results show that, for plots with the *H standard*, the adoption of the *H standard* decreases wheat yield and quality

attributes. Adopting the *H standard* on a plot in comparison to the *L standard* reduces yield by 150 kg/ha, representing a 2.5% decrease in yield. In addition, it decreases test weight by 0.54 kg/hl and protein content by 0.02 points. Our results thus indicate that banning the most toxic pesticides at the plot level to limit the negative impact of agricultural practices on biodiversity (as required by the *H standard*) has an overall negative effect on technical outcomes. This is in line with the study by Begg *et al.* (2017) who suggest that biodiversity improvements, thanks to the implementation of conservation practices, often fail to improve crop yield. Several reasons may explain why we do not find a positive relationship between yield and the adoption of practices aimed at favouring biodiversity. Firstly, the requirements of the *H standard* may not be stringent enough. Moreover, the implementation of practices on a small area such as a plot, may not be sufficient to significantly improve biodiversity. Coordination among farmers may be needed to ensure a spatial coordination in the adoption of environmental practices (Franks, 2011; Westerink *et al.*, 2017). Finally, despite a plot being under the *H standard*, the practices on neighbouring plots may be harmful and limit the effect of *H standard* practices on biodiversity.

Table 3.4. Second-stage coefficient estimation – outcome equations

Dependent variable	(1) Yield	(2) Test weight	(3) Protein content	(4) Wheat price
Mineral N quantity	0.013** (0.005)	0.036*** (0.009)	-0.003 (0.003)	0.038** (0.018)
Herbicide TFI	0.306 (0.327)	1.534*** (0.457)	0.064 (0.122)	0.932 (0.995)
Insecticide TFI	0.558 (0.384)	0.488 (0.881)	-0.059 (0.243)	4.061** (1.829)
Fungicide TFI	0.844*** (0.284)	-0.419 (0.425)	-0.068 (0.170)	0.472 (1.075)
Corn as previous crop dummy	-0.083 (0.145)	0.109 (0.255)	-0.090 (0.070)	-3.061*** (0.441)
Tillage dummy	0.252** (0.088)	-0.097 (0.156)	0.117** (0.047)	3.763*** (0.358)
High quality varieties dummy	0.209 (0.185)	0.867*** (0.213)	0.043 (0.084)	2.061*** (0.538)
Plot size	-0.009 (0.010)	0.006 (0.023)	0.004 (0.005)	-0.033 (0.045)
H standard experience dummy	-0.240** (0.106)	-0.196 (0.135)	0.003 (0.053)	0.143 (0.417)
Livestock dummy	0.182 (0.184)	0.578** (0.264)	0.102 (0.100)	3.342*** (0.632)
Temperature	-0.087 (1.106)	2.724 (1.895)	-0.552 (0.505)	1.694 (4.771)
Precipitation	0.042 (0.067)	0.113 (0.120)	-0.062* (0.033)	-0.116 (0.331)
Temperature * Precipitation	-0.003 (0.005)	-0.008 (0.008)	0.004* (0.002)	0.009 (0.023)
H standard dummy	31.600* (20.264)	87.640*** (25.825)	-18.258** (7.568)	124.00** (69.735)
Mineral N quantity * H standard	-0.006 (0.006)	-0.025*** (0.009)	0.008** (0.003)	-0.039** (0.023)
Herbicide TFI * H standard	0.557 (0.384)	-1.689*** (0.564)	0.087 (0.168)	2.416 (1.156)
Insecticide TFI * H standard	-1.153* (0.668)	-0.404 (0.869)	-0.110 (0.260)	-4.969** (1.983)
Fungicide TFI * H standard	-1.252*** (0.345)	0.304 (0.511)	-0.068 (0.170)	-1.356 (1.311)
Corn as previous crop * H standard	0.643** (0.201)	0.281 (0.298)	0.017 (0.091)	3.146*** (0.540)
Tillage * H standard	-0.557*** (0.160)	-0.172 (0.193)	-0.029 (0.077)	-3.782*** (0.467)
High quality varieties * H standard	-0.581*** (0.206)	-0.553** (0.241)	-0.105 (0.094)	-0.929 (0.573)
Plot size * H standard	0.009 (0.012)	0.013 (0.025)	-0.012** (0.006)	-0.006 (0.044)
H standard experience * H standard	0.266 (0.180)	0.463** (0.195)	-0.035 (0.076)	0.613 (0.573)
Livestock * H standard	-0.196 (0.205)	-0.831*** (0.290)	-0.048 (0.102)	-3.473*** (0.634)
Temperature * H standard	-1.947 (1.384)	-5.525*** (1.783)	1.092** (0.530)	-7.790* (4.733)
Precipitation * H standard	-0.107 (0.076)	-0.300** (0.119)	0.102*** (0.034)	-0.294 (0.328)
Temperature * Precipitation * H standard	0.007 (0.005)	0.021** (0.008)	-0.007*** (0.002)	0.019 (0.022)
Generalised residuals	0.068 (0.073)	0.260* (0.140)	0.033 (0.038)	1.741*** (0.318)
Generalised residuals * H standard	-0.414 (0.262)	-0.487* (0.256)	-0.071 (0.105)	-1.735*** (0.569)
Constant	3.786 (16.105)	29.578 (27.467)	21.591*** (7.269)	151.470*** (69.957)
R^2	0.11	0.34	0.27	0.79

<i>Wald test</i> $\chi^2(49)$	2.4e+07***	1.8e+06***	7.6e+05***	1.9e+06***
<i>Wald test on generalised residuals</i> $\chi^2(2)$	3.28	7.27**	1.04	44.34***
<i>Anderson-Rubin test</i>	45.50***	86.27***	19.88***	47.79***
<i>Wald test on instruments</i> $\chi^2(8)$	32.22***	58.52***	15.79**	52.71***
Number of observations	8,015	8,015	8,015	8,015

*, **, *** indicate significance at the 10%, 5% and 1% levels, respectively.

Note: We include the year's dummy variables and small agricultural region dummy variables but do not show the results. Bootstrap standard errors are presented in parentheses.

Table 3.5. Treatment effects on the treated (TT) – Effect of the H standard on outcome variables

Sub-samples: Plot with <i>H standard</i>	Decision stage		Treatment effects
	To adopt <i>H standard</i>	To adopt <i>L standard</i>	
Yield	5.96 (0.02)	6.11 (0.02)	TT = -0.15***
Test weight	79.27 (0.03)	79.81 (0.04)	TT = -0.54***
Protein content	12.13 (0.01)	12.15 (0.01)	TT = -0.02**
Wheat price	172.59 (0.16)	171.40 (0.16)	TT = 1.19**

*, **, *** indicate significance at the 10%, 5% and 1% levels, respectively.

3.4.3. Effect of H standard adoption on economic outcome – wheat price

Farmers receive monetary incentives to produce high quality wheat through a specific price premium. The price formula is based on a bonus-penalty system depending on the different quality attributes. As seen above, the adoption of the *H standard* over the *L standard* negatively affects quality for our sample. It would also indirectly have a negative effect on economic outcome through a penalty on the base price. However, farmers also receive monetary incentives for adopting more stringent environmental standards: the higher the requirements, the higher the price premium. Therefore, we now assess whether the price premium of the *H standard* compensates for its negative effect on quality; that is to say, what is the effect of adopting the *H standard* on wheat price (the latter includes both the quality bonus-penalty value and the standard's premium).

We present the results of the second-stage of the ESR model for wheat price in column (4) of Table 3.4. The estimated coefficient of the generalised residuals term ρ_0 is significant and positive ($\rho_0 = 1.741***$). This indicates a negative selection bias for plots producing under the *L standard*. It suggests that the plots with lower than average wheat price are more likely to adopt the *L standard*. The *H standard* variable is statistically significant, revealing a strong

positive effect of adoption of this standard on wheat price. Results also show that wheat price significantly depends on agricultural practices and farm characteristics. In addition, some interaction terms of explanatory variables with the *H standard* variable are significant, suggesting differences in technologies and the presence of heterogeneity in our sample.

Table 3.4 reports the TT of the *H standard* on wheat price. It shows that the adoption of the *H standard* for plots adopting the *H standard* increases wheat price by €1.19/ton. This is a low increase, as wheat price fluctuation is much higher than this across years. We conclude that the *H standard* price premium merely compensates for the negative effect of the *H standard* adoption on quality. The monetary benefits for farmers when they adopt the environmental standard with the higher requirements, the *H standard* (limiting toxic pesticides for biodiversity), are low.

Our analysis highlights that the adoption of the *H standard* over the *L standard* negatively affects yield and quality outcomes, and that farmers receive low monetary benefits from implementing the standard with the higher requirements (*H standard*). Other reasons may thus explain why farmers choose to change their practices and adopt the *H standard* although they receive low economic incentives. The literature reports various non-monetary motivations toward the adoption of environmental practices and standards (Ambec and Lanoie, 2008; Baumgart-Getz *et al.*, 2012; Lanoie and Llerena, 2015; Dessart *et al.*, 2019; Thompson *et al.*, 2023). Firstly, the adoption of the *H standard* may enable farmers to access to a different market and diversify their selling outlets. Secondly, the adoption of the *H standard* could also be motivated by access to information and knowledge on environmental practices. Indeed, adopting the standard on some plots implies that farmers receive technical visits from the cooperative's advisors at least four times a year. Furthermore, the effect of social factors should not be underestimated. The cooperative studied is deeply involved in the development of environmental labels, and thus, the adoption of the *H standard* may facilitate connections with the cooperative members and local networks. Finally, environmental concern and awareness of farmers can also be drivers of the adoption of the *H standard*.

3.5. Conclusion

We contribute to the existing literature by investigating the effects of the adoption of a more stringent environmental standard on technical and economic outcomes for wheat production at the plot level in France from 2014 to 2020. We compare two standards which aim to preserve

biodiversity but with different levels of stringency. Measuring the level of uptake of environmental practices is not straightforward, and it may be difficult to distinguish clearly between low and high uptake (Barnes *et al.*, 2021). For this reason, using labels with clear sets of requirements is a robust approach. The less stringent standard (*L standard*) requires the presence of biodiversity habitats. The more stringent one (*H standard*) bans the most toxic pesticides and encourages the preservation of biodiverse habitats in order to reduce the negative effects of agricultural practices on biodiversity. The sets of rules for these two standards are an intermediate level between the organic standard and conventional practices. We analyse the effect of adopting the more stringent environmental standard at the plot level on wheat price, yield and quality, the latter consisting of two attributes: test weight and protein content. We choose to focus on these attributes since farmers receive monetary incentives to improve them through a marketing contract. Thus, a decrease in these two quality attributes would negatively affect the farm's economic outcome. Wheat price is the economic outcome by which we estimate the effect of the adoption of the more stringent environmental standard.

Our results show that banning the most toxic pesticides at the plot level (through adoption of the more stringent standard) has a negative effect on technical outcomes: it decreases yield by 2.5%, test weight by 0.54 kg/hl and protein content by 0.02 points, on average. Our results also highlight the importance of considering quality effect along with yield effect when estimating the effect of the adoption of environmental practices. The adoption of a higher environmental standard induces an average increase in wheat price of €1.19/ton, which is lower than wheat price fluctuation across years. The price premium of the higher environmental standard merely compensates for the negative effect of the standard's adoption on quality. Thus, monetary benefits for farmers adopting the higher environmental standard, limiting toxic pesticides for biodiversity, are low.

From a public policy point of view, intermediate environmental standards such as those investigated here may be interesting instruments to favour biodiversity, since their adoption rate is higher than that for the organic standard. The *H standard* appears to be an instrument that could be worth implementing in pursuit of the Farm to Fork goal of reducing by 2030 the risk of chemical pesticides by 50%, as most toxic pesticides are prohibited under its conditions. However, results show that the economic incentives that compensate for the negative effect on technical outcomes are low. Although the literature highlights non-monetary motivations behind the adoption of environmental practices and standards (access to different markets, access to information, knowledge on sustainable practices, connection with a local network,

environmental awareness, risk tolerance, and social factors (Ambec and Lanoie, 2008; Baumgart-Getz *et al.*, 2012; Lanoie and Llerena, 2015; Dessart *et al.*, 2019)), it is not clear that such non-monetary motivations are sufficient for the adoption of this standard on a larger scale. It should be highlighted that our study focuses on plots cultivated by farmers who are members of a cooperative aiming at the development of environmental standards. This is therefore a specific sample of farmers, whose behaviour may not be generalizable to others. It is possible that the behaviour of our sample's farmers is influenced by shared non-monetary motivations as well as shared monetary motivations that extend beyond monetary benefits. These motivations may include having access to diverse markets and expanding the range of selling outlets. To up scale the adoption of the H standard, economic incentives should be carefully designed. Accompanying public policies could be designed to achieve higher participation and spatial coordination in order to obtain a better environmental impact. Moreover, to ensure the development of a standard on a larger scale, it is not enough simply to focus on the supply side, it is also necessary to increase demand on a larger scale.

We could suggest a number of possible further research avenues. Firstly, it would be useful to assess the margin effect at the plot level of the adoption of the more stringent environmental standard. When adopting this standard, production costs might be reduced, since farmers use pesticides which are less toxic and taxes on pesticides are toxicity-dependent in France. Unfortunately, our database does not contain information on production costs. We were only able to collect price information to take into account potential revenue. Furthermore, farm-level information would give us more information with which to assess the effects of the adoption of environmental standards on farms' performance. Bravo-Ureta *et al.* (2020) showed that, while plot-level management does not have a significant effect on farm efficiency, farm-level management does. Analysing farm performance would enable the farm's multi-output strategy to be studied. Trade-offs could be measured, relating to economic and environmental performances at the farm level, when farmers adopt environmental standards with different levels of stringency on different plots. In addition⁶, to confirm the environmental benefits of the H standard adoption, it would be worthwhile to explore indicators on pesticides that take into account the associated risk, such as the Harmonised Risk Indicator 1 and the Load Index. Finally,⁷ further investigation of weather aspects could be undertaken when estimating wheat yield. Climate change may have adverse effects on crop yields and agricultural production risk

⁶ We thank one Reviewer who raised this issue.

⁷ We thank one Reviewer who raised this issue.

(Ray *et al.*, 2012; Nelson *et al.*, 2014; Gammans *et al.*, 2017; Arora *et al.*, 2020; Anderson *et al.*, 2023). It means that a risk analysis of agricultural production must be conducted ex-ante, treating weather shocks as uncertain (Chavas *et al.*, 2019; Chavas *et al.*, 2022). However, integrating weather variables observed in the same year of wheat production and environmental standard, as we did in this article, could be problematic as it implies that weather is known. Thus, weather aspects in previous years should be included, so that weather shocks can be serially correlated.

3.6. Appendix

Table 3A.1. Falsification test – Test on the validity of the instrument

Dependent variable	Yield	Test weight	Protein content	Price
Mineral N quantity	0.013** (0.006)	0.037*** (0.008)	-0.003 (0.003)	0.046** (0.019)
Herbicide TFI	0.348 (0.249)	1.560*** (0.383)	0.074 (0.134)	1.203 (1.106)
Insecticide TFI	0.547 (0.496)	0.363 (0.774)	-0.097 (0.241)	2.912 (1.947)
Fungicide TFI	0.841*** (0.286)	-0.454 (0.402)	-0.071 (0.143)	0.264 (1.022)
Corn as previous crop dummy	-0.030 (0.127)	0.290* (0.170)	-0.065 (0.054)	-1.821*** (0.489)
Tillage dummy	0.174* (0.102)	-0.285** (0.144)	0.084* (0.049)	2.366*** (0.391)
High quality varieties dummy	0.174 (0.206)	0.835*** (0.294)	0.030 (0.084)	1.719** (0.692)
Plot size	-0.012 (0.011)	0.002 (0.016)	0.003 (0.006)	-0.068 (0.042)
<i>H standard</i> experience dummy	-0.265*** (0.100)	-0.261 (0.166)	-0.008 (0.054)	-0.334 (0.365)
Livestock dummy	0.195 (0.236)	0.592** (0.272)	0.106 (0.088)	3.474*** (0.702)
Temperature	-0.140 (1.209)	2.590 (1.668)	-0.575 (0.406)	0.710 (4.176)
Precipitation	0.039 (0.074)	0.104 (0.107)	-0.063** (0.028)	-0.177 (0.265)
Temperature * Precipitation	-0.003 (0.005)	-0.008 (0.008)	0.004** (0.002)	0.012 (0.018)
Highway dummy	0.168 (0.105)	0.228 (0.151)	0.066 (0.047)	2.050*** (0.382)
Constant	4.632 (17.391)	31.583 (24.461)	21.952*** (6.051)	166.443*** (60.299)
R^2	0.15	0.11	0.29	0.75
<i>Wald test</i> $\chi^2(23)$	973.87***	2668.20***	2421.97***	14883.18***
<i>Wald test on instrumental variables</i> $\chi^2(1)$	2.55	2.28	1.95	31.28***
Number of observations	2,789	2,789	2,789	2,789

*, **, *** indicate significance at the 10%, 5% and 1% levels, respectively.

Note: We include year's dummy variables and small agricultural region dummy variables but do not show the results. Bootstrap standard errors are presented in parentheses.

3.7. References

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Chapter 4. How can cooperatives promote environmental practices? A choice experiment to identify contracting strategies in the wine sector

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4.1. Introduction

In France in 2022, 2.88 million hectares of land were cultivated using organic farming practices, accounting for 10.7% of the country's Utilized Agricultural Area (UAA) and involving nearly 60,000 farmers (L'Agence BIO, 2023). Thanks to the support of public policies through subsidies and the development of dedicated supply chains, conversions to organic farming have increased in recent years. We observe a significant conversion trend since 2015, witnessing annual increases of more than 10% in the agricultural land dedicated to organic farming. However, the year 2022 seems to mark a turning point with a slowdown in the growth dynamics, featuring only a 2.7% increase in the area cultivated under organic farming. This growth rate falls short of the targets set by the European Green Deal at the European level and those announced by France. France sets a target of 18% of agricultural land under organic farming by 2027 in its National Strategic Plan in response to the Green Deal objective of cultivating 25% of agricultural land under organic farming by 2030 (European Commission, 2020; Ministère de l'agriculture et de la souveraineté alimentaire, 2022).

To achieve the ambitious organic conversion objectives set by the French government and European Commission, barriers to conversion need to be removed. Yet, many farmers still face barriers to converting into organic farming, as it requires meeting stringent requirements that entail adopting new environmental practices and redesigning the farming system. The farm structure, the socio-demographic characteristics of farmers and behavioral factors influence the adoption of organic farming (Latruffe and Nauges, 2014; Dessart *et al.*, 2019; Serebrennikov *et al.*, 2020; Sapbamrer and Thammachai, 2021). Dessart *et al.* (2019) distinguish three types of behavioral factors: (1) dispositional factors which relate to farmers' general tendency to behave in a certain way such as personality, risk tolerance and environmental concerns, (2) social factors which encompass norms and signaling motives, and (3) cognitive factors which involve aspects of learning and reasoning. They emphasize that the study of behavioral factors is crucial for tailoring policy design to promote and support the adoption of environmental practices. Serebrennikov *et al.* (2020) and Sapbamrer and Thammachai (2021) highlight the important effect of sources and information and extension agents in promoting the adoption of organic farming. In addition, Sapbamrer and Thammachai (2021) underline that governments subsidies and market environment affect the adoption of organic farming.

Indeed, organic products can be regarded as vertically differentiated products in the market. Some consumers are thus willing to pay a premium to get these products giving market

opportunities to farmers to increase their revenue. As agricultural cooperative hold 40% of the total agri-food market shares (La coopération agricole, 2022), they are key stakeholders in the agri-food supply chain and they can thus play a role in encouraging the adoption of organic farming. Their governance organization favors a close relationship with farmers. They can participate both upstream by supplying inputs and downstream by managing the farm production sales. Supply chains stockholders have incentives to invest in product differentiation. Cooperative organizations enable farmers to secure their markets by expanding their market shares in existing markets or creating new market opportunities (Ambec and Lanoie, 2008; Candemir *et al.*, 2021; Duvaleix *et al.*, 2020). Agricultural cooperatives can influence farms' production choices through the contracts they offer to their members. They may enforce specific practices adoption and the purchase of specific inputs through production contracts, or encourage quality standards adoption using marketing contracts (Goodhue, 2011; Hao *et al.*, 2018; Swinnen and Kuijpers, 2019; Duvaleix *et al.*, 2020). Several empirical studies highlighted cooperatives' positive effect in incentivizing farmers to adopt environmentally friendly practices (Candemir *et al.*, 2021). While it can be challenging for agricultural cooperatives to influence dispositional factors (such as openness to new experiences, risk seeking, environmental concerns, and farming objectives) – as they are not directly tied to a specific decision and tend to be relatively stable over time – they can exert greater influence on social and cognitive factors. Social norms play a significant role within social factors, and they can be categorized into two types. Descriptive norms come into play when practices are shaped by the observed behaviors of others, while injunctive norms are at work when practices are influenced by what individuals believe others anticipate from them (Dessart *et al.*, 2019). Agricultural cooperatives can influence descriptive norms by favoring relationships among their members, allowing them to observe each other's farming practices. When the adoption rate of organic farming is high enough, agricultural cooperatives can promote it among conventional farmers, who then may be willing to adopt organic farming to do as the majority. Agricultural cooperatives also have an important role to play in terms of injunctive norms because the expectations of the cooperative's advisors can positively influence the adoption of organic farming. Regarding cognitive factors, previous studies highlight that adoption of specific sustainable practices is higher when farmers have sufficient knowledge and skills related to these practices, and when they believe that these practices can increase their benefits with limited risks (Dessart *et al.*, 2019). Cooperatives also provide technical advice and training (Naziri *et al.*, 2014; Wossen *et al.*, 2017; Duvaleix *et al.*, 2020; Yu and Huang, 2020). They could also get more involved in economic advice to de-bias monetary cost and benefits

perception. The present bias can be significant, it implies that immediate benefits and costs carry more weight in decisions compared to equivalent benefits and costs in the future (Doyle, 2013). To mitigate the risk perception of organic farming, cooperatives can also implement mutual funds to offset potential yield losses.

To examine more in depth the potential role of agricultural cooperatives in encouraging farmers to adopt organic farming practices, we first analyze farmers' preferences for different contracts in a wine cooperative. We chose the wine sector as the focus of our case study due to its important reliance on pesticides. The sector faces a major challenge in aligning with societal expectations by reducing or eliminating pesticide usage, as is the case in organic farming. Second, we intend to categorize winegrowers profiles based on their willingness to adopt organic farming. The decision to conduct an experiment was motivated by the scarcity of statistical data on contracts between farmers and cooperatives, as they are considered confidential (Magrini *et al.*, 2023). We thus conducted a discrete choice experiment (DCE) with all the 70 winegrowers of a wine cooperative who looks for encouraging its members to adopt organic farming. Given that farming contracts encompass various distinguishable attributes, employing the DCE methodology to assess the impact of these attributes on the likelihood of adopting an alternative contract is well-founded. We examine several contract attributes whose objective is to encourage winegrowers to adopt organic farming: (1) the option to get a cooperative advisor to assess the impact of practice changes on the economic performance of the vineyard and the farm labor organization, (2) the opportunity of contracting for only 50% of the vineyard area, (3 and 4) the pricing formula, encompassing the potential to receive a 30% premium on the base price and the access to a compensation mechanism to cope with yield loss.

Our article stands out from the DCE literature by focusing on farming contracts between cooperatives and farmers. To our knowledge, few DCEs focus on farming contracts with environmental requirement attributes. Most studies have investigated farmers' preferences regarding agri-environmental policies, particularly the design of agri-environmental schemes (see Mamine and Minviel (2020) for a meta-analysis). DCEs by exploring farmers preferences can contribute to improving the design of these schemes to make them more efficient (Latacz-Lohmann and Breustedt, 2019). Moreover, the DCEs conducted on farming contracts are mainly carried out in developing countries, where challenges differ from those in developed countries (Abebe *et al.*, 2013; Van den Broeck *et al.*, 2017; Fischer and Wollni, 2018; Ola and Menapace, 2020; Widadie *et al.*, 2021). The limited number of DCEs carried out on farming

contracts in developed countries do not focus on environmental requirement attributes (Sauthoff *et al.*, 2015; Vassalos *et al.*, 2016) with the exception of Weituschat *et al.* (2023). Weituschat *et al.* (2023) show that farming contract is a potential strategy to encourage the adoption of environmental practices among specific wheat producers in Italy. The environmental practices studied include integrating legume or oil crop in the rotation, cultivating flower strips, and prohibiting the use of glyphosate. Given the complementary role farming contract proposed by cooperatives can play alongside public policies to incentivize the adoption of organic farming, our aim is to contribute to this literature gap through a case study.

The rest of the article is organized as follows. In section 2, we provide an overview of the context and challenges within which our study was conducted. We describe the experimental design of the DCE and present the econometric modelling approach. Section 3 is dedicated to introducing our winegrower sample, providing insights into their characteristics, their relation with the cooperative and their perception of organic farming. Moving on to Section 4, we present the DCE results, delving into the preferences of winegrowers concerning the various attributes of the contracts being examined. We conclude in section 5.

4.2. Methods

In this paper, we analyze the preferences of winegrowers for different contracts offered by their agricultural cooperative. Beside the choice experiment, the survey elicited information about the socio-demographic characteristics of the winegrowers and their farm.

4.2.1. The case study

In the wine sector, the cooperative network is well developed. According to “la Coopération Agricole”¹, by 2022 there will be 570 cooperative wineries in France and 58% of winegrowers will belong to a cooperative winery. About half of the wine produced in France comes from cooperative wineries. The weight of cooperatives in the sector is therefore considerable and the cooperative can have a significant impact on improving agricultural practices.

¹ The “Coopération Agricole - Vignerons Coopérateurs de France” represents the cooperative wine cellars and unions of cooperative wine cellars grouped within departmental federations. <https://www.lacooperationagricole.coop/filieres/vignerons/mieux-connaître-les-vignerons-cooperateurs>

The experiment was carried out with members of a wine cooperative in a region, *Lot-et-Garonne*, in the south west of France. In this area, the wine cooperative gathers 95% of the total production. The remaining production is done by some farmers that use direct selling. All the wines produced by the cooperative are covered by the *Buzet* Protected Designation of Origin (PDO) and thus winegrowers must fulfil the set of rules defined in the French *Arrêté du 22 août 2019*². In our study, we only consider farms that are commercial units and thus wine activity is part of their income revenue, we call these farms *active* farms. We conducted our survey with all these active members of the wine cooperative excluding those who produce under organic certification. Winemaking is done by the wine cooperative. This is a distinct profession requiring extensive knowledge and significant material investment. The wine cooperative by pooling grape production is able to finance this processing stage.

Reducing the use of pesticides, fungicides and herbicides is a major challenge for agriculture and specifically for the wine sector, which is a major pesticide user. There exist major social issues associated with the use of synthetic chemical inputs, which affect the health of all people within a wine area (farmers, consumers and local residents). To meet society's expectations, the studied wine cooperative has initiated an environmental transition by encouraging changes in its members' practices.

The *Vignerons de Buzet* cooperatives aim at differentiating on the market more broadly the *Buzet* PDO with environmental standards. Since 2004, the wine cooperative develops the use of environmental standards for their members, first with the French environmental standard *Agriconfiance* then with the French High Environmental Value (*HEV*) standard³. Now, the wine cooperative achieves that all its members meet the *HEV* standard. The cooperative's declared aim is to achieve the total elimination of all synthetic chemical inputs and the preservation of living soils within the PDO area. In order to encourage members to move towards organic standard, it is worth identifying the drivers that can be used in contracting between the winegrowers and the cooperative. To this end, a DCE was carried out, offering different sets of contract to identify what matters for winegrowers to improve their environmental practices.

² https://info.agriculture.gouv.fr/gedei/site/bo-agri/document_administratif-157abec9-d546-4a2b-8b7c-779b3a6fa8e8/telechargement consulted on September 21st, 2023

³ Both the *Agriconfiance* and *HEV* standards are based on requirements specifications aimed at reducing the use of chemical pesticides and nitrogen fertilizers, optimizing irrigation management, and promoting biodiversity. The *HEV* standard is more stringent than the *Agriconfiance* standard.

4.2.2. Experimental design

In a choice experiment, participants have to reveal their preferences by choosing from a set of alternatives (Adamowicz *et al.*, 1998; Street and Burgess, 2007). The alternatives are defined in terms of attributes that characterize the contract. Each contract attribute consists of several levels, so that the contract can be defined as a whole.

The choice experiment was conducted with the 70 active non-organic winegrowers, members of the cooperative. During the choice experiment, each winegrower were confronted with the choice among the three alternatives contracts for 6 choice situations (corresponding to 6 tasks). One of the three alternatives represents the status quo and was therefore identically repeated in each choice situation. It has been highlighted in the literature that when the status quo is ill-designed, it can influence the DCE results. It thus is recommended to avoid specifying an imprecise status quo that does not take into account individuals' subjective perceptions or the initial situation they are facing (Barton and Bergland, 2010; Domínguez-Torreiro and Soliño, 2011; Ahtiainen *et al.*, 2015). In the DCE presented to the winegrowers, the status quo corresponds to the current contract that farmers have with the cooperative. All farmers have the same status quo since the cooperative currently offers one single contract, and furthermore, the winegrowers do not have a short-term option that allow them not to enter into a contract with the cooperative.

The characterization of the contracts was carried out in collaboration with the cooperative's management and technical advisors. The aim was to offer contract options with characteristics (attributes) that were consistent with the characteristics of the contracts already offered by the cooperative and that could be adjusted to levels that would encourage the adoption of less polluting practices. These discussions enabled us to formulate hypotheses about the potential drivers to be used in contracting. Thus, each attribute defined in the choice experiment can be used to provide answers about the potential drivers that can be used. The choice experiment and the questionnaire were carried out face-to-face. The interview was conducted by an experimenter who was not employed by the cooperative, and the participants were told that the collected data would be anonymized and that the cooperative would not have access to the individual collected data.

We defined five attributes, which means that these five attributes characterized each contract offered to the winegrowers. Table 4.1 summarizes the contract attributes and their attribute levels.

Table 4.1. Description of contract attributes and attribute levels used in the choice set design

Contract attributes	Attribute levels	Variable names
<i>Access to individual support</i>	Technical (SQ)	support_tech
	Techno-economic	support_tech-eco
	Techno-economic and labor organization	support_tech-eco-orga
<i>Vineyard area contracted</i>	100% (SQ)	area_100%
	50%	area_50%
<i>Environmental requirement</i>	HEV (SQ)	requirement_MQS
	Organic farming and conservation agriculture	requirement_organic Requirement_organic-CA
<i>Payment</i>	Base rate (SQ)	payment_base
	Base rate + 30%	payment_base+30%
<i>Compensation for yield reduction</i>	Annual yield target (SQ)	compensation_annual-target
	Externalize	compensation_externalize
	Cooperative Fund	compensation_coop-fund
	Guaranteed income per hectare	compensation_guaranty-ha
	Multi-year yield target	compensation_multi-year-target

SQ: Status Quo

The first attribute, *access to individual support*, aims to determine the extent to which the type of support offered by the cooperative is a determining factor when a winegrower chooses a contract. It therefore makes it possible to consider the type of support that should be favored in order to enable a change in agricultural practices. This attribute is subdivided into three levels: technical support (aimed at guiding the winegrower in his choices of production techniques), technical-economic support (enabling the cooperative the winegrower to evaluate with the cooperative advisor his choices regarding the economic performance of his vineyard) and, finally, technical-economic and labor organization support (offering a level of support that includes technical, economic and labor organizational aspects).

The second attribute, *vineyard area contracted*, is used to determine whether the contract area has an impact on the choice of contract. This attribute defines the area covered by the contract and can take two levels: 100% and 50%. As described by Mamine and Minviel (2020), numerous studies have shown a significant impact of the area dedicated to agri-environmental schemes, and we want to test whether this result holds for cooperative contracts.

The third attribute, *environmental requirement*, describes the level of requirements required on the hectares under the contract. Three levels are offered: HEV (status quo), organic farming and organic farming combined with conservation farming. Conservation agriculture is based on the following three principles: i) minimum soil disturbance (establishment of crops without mechanical tillage and with minimum tillage since the harvest of the previous crop) ii) permanent soil cover iii) intercropping (crop rotation is not possible for perennial crops). It should be noted that the combination of conservation agriculture and organic farming is challenging for farmers, as organic farming aims to avoid the use of synthetic inputs, whereas conservation agriculture aims to limit tillage. However, the joint development of these two types of practices is increasingly seen as an objective (Fleury *et al.*, 2014; Peigné *et al.*, 2015; Boeraeve *et al.*, 2022).

The fourth attribute, called *payment*, includes two pricing options: a basic price and an increase in the basic price by a rate of 30%. This price attribute was defined to reflect the common cooperative pricing formula. Members are usually offered a basic price that is fully earned when the target yield is reached (if the performance target is not met, the full amount of the payment is not transferred). The 30% premium represents the premium currently granted to members when producing under organic certification.

Finally, the last attribute, *compensation for yield reduction*, aims to characterize the potential compensation for yield loss. This attribute is categorized into five levels. At the time of the experiment, the wine cooperative linked the receipt of the full basic price to a minimum annual yield. The status quo situation is therefore defined by this level, called the *annual yield target* which do not secure any yield loss. In the status quo, winegrowers do not get a compensation when the target yield is not reached. The other four attribute levels are: a performance pluri-annual target (the performance target required by the cooperative is determined over a three-year period), externalized compensation (by underwriting an insurance contract), a compensation cooperative fund (the cooperative sets a pooling fund to cover the economic yield loss) and finally, a guaranteed income per hectare (a fixed income per hectare whatever the achieved yield).

With 5 attributes associated with 2 to 5 levels, the full factorial design is too large (360 combinations) to implement. Therefore, choice sets are the result of D-efficient design using modified Fedorov algorithm (Carlsson and Martinsson, 2003) with priors defined from a pilot experiment. Each choice set is composed of the status quo and two alternative scenarios, as shown in the example presented appendix (Figure 4.A1, translated from French).

4.2.3. Survey

Many studies have examined the determinants of adoption of sustainable agricultural practices (for a review of this literature, see Dessart *et al.* (2019); Mamine and Minviel (2020); Sapbamrer and Thammachai (2021); Serebrennikov *et al.* (2020)). Individual farmer characteristics appear to have systematically a significant impact on the choice of production practices. For this reason, after the choice experiment, the participants answered a questionnaire that allowed us to elicit information about individual characteristics of each winegrower and his farm. The questionnaire itself is divided into three parts.

The first part focuses on the characteristics of the farm and the winegrower. It allows us to characterize each farm according to its surface area, the number of production units, the sales and marketing channels, the type of standards currently implemented on the vineyard, as well as the usual socio-demographic characteristics of the farmer.

In the second part of the questionnaire, we elicit information about training and diagnosis for winegrowers. The aim is to assess the perception of the training activities carried out and to identify the winegrowers' expectations in terms of training format and tools.

Finally, the third part of the questionnaire aims to identify the determinants of changes in agricultural practices. We look for characterizing the winegrowers' positioning in relation to their own practices (what tools are used to improve agricultural practices, what are the objectives linked to grapes production, what is the positioning associated with decisions on farming practices, etc.) and those of other farmers.

4.2.4. Econometric modelling

When analyzing choice data, the aim is to understand the impact of the contract attributes of the different alternatives offered to the agents' level of utility. We use a random parameters logit model, also called mixed logit (MXL), which extend the standard conditional logit model (McFadden, 1973). To do so, we use discrete choice models that allow us to estimate to what extent each contract attribute contributes the utility level for each choice set and each attribute level combination in each choice set.

Thus, we estimate a logit model with random parameters taking into account preference heterogeneity and panel data structure. The utility U for a winegrower i choosing the contract alternative a in a choice situation t is given by U_{iat} :

$$U_{iat} = \beta_i X_{iat} + \alpha W_{iat} + \delta(X_{iat} \cdot Z_i) + \varepsilon_{iat} \quad (1)$$

β_i are random coefficients that vary over individuals in the population and X_{iat} is a vector of alternative specific variables that define the environmental requirement of the alternative. We consider random coefficients for the variables characterizing environmental requirements, thus assuming that preferences for environmental quality are heterogeneous across participants (we consider Gaussian-distributed coefficients). It follows that the vector X_{iat} contains three dichotomous variables: three level of environmental requirements (HEV being the reference attribute level (*ref.*), Organic farming and Organic and conservation agriculture) for each of the three alternative contracts. α is a vector of fixed coefficients and W_{iat} , a vector of alternative-specific variables. The vector W_{iat} contains the variables corresponding of the levels of the other attributes for each alternative. The effects of individual characteristics are identified by the interaction between the individual characteristics and the environmental requirement $X_{iat} \cdot Z_i$. ε_{iat} is a random term that follows a type I extreme value distribution.

The probability that individual i choose alternative a ($a = \{1,2,3\}$) in the choice situation t ($t = \{1, \dots, 6\}$), conditional on the random parameter β_i is:

$$P_{iat}(\beta) = \frac{\exp(\beta_i X_{iat} + \alpha W_{iat} + \delta(X_{iat} \cdot Z_i))}{\sum_{a=1}^3 \exp(\beta_i X_{iat} + \alpha W_{iat} + \delta(X_{iat} \cdot Z_i))} \quad (2)$$

The Log-likelihood function is approximated by using 500 pseudo Monte Carlo draws, and the convergence to a global maximum of the likelihood function is ensured using a simplified version of the algorithm proposed by Bierlaire *et al.* (2010)⁴.

We estimate four different specifications. The first specification, model (1), integrates only alternative specific variables. The characterization of individuals according to their risk preference was included in the model (2). The third specification estimates whether the feeling of being well prepared for the transition to organic farming has an impact on the choice of contract. Finally, the fourth model integrates all the individual variables included in models 2 and 3. Results are commented in section 4 and presented in Table 4.5.

Afterwards, we analyze whether there is a segmentation of winegrowers according to their responses to the choice experiment. To do this, we conducted a latent class analysis on model 1 (without interaction terms). In a Latent Class model, heterogeneity is accommodated by making use of separate classes with different values for the vector β' in each class. We tested latent class models with two, three and four classes. The four-class model could not be estimated because the number of parameters to be estimated was too high compared to the number of observations in our sample. Based on the log-likelihood, McFadden's pseudo-R², and the Akaike Information Criterion (AIC), the three-class model is preferred. The results are shown in Table 4.6. Non-parametric tests (Wilcoxon rank sum test for continuous variables and Fisher's exact test for discrete variables) were used to discuss differences in individual characteristics of winegrowers between each class.

4.3. Empirical data

4.3.1. Characteristics of winegrowers

We interviewed the 70 farm managers who are members of *Les Vignerons de Buzet* cooperative. The characteristics of both the winegrowers and their farms are presented in Table 4.2. The average age of the interviewed winegrowers is 51 years old, with over half of them having pursued higher education. It is worth noting that the farm structures are diverse. Nearly two-thirds of the farms in our sample are not specialized in grape production and have another production. In most cases, those farms have field crops (50%) or vegetables/fruits production

⁴ The estimations were carried out with R using the Appollo package (Hess and Palma, 2019).

(13%). We also observe diversity in farm size and the use of seasonal labor. Moreover, the primary goals of the winegrowers are diverse. The two most mentioned objectives are “increasing income” and “balancing work and family life”. “Farming while improving environment” was cited as the main objective for only 10% of the winegrowers.

Table 4.2. Descriptive statistics on farm and farmers characteristics

Variables	Mean	Standard deviation
<i>Farm characteristics</i>		
Legal form – individual (%)	34.3	
Utilized agricultural area (ha)	70.6	83.7
Family labor (labor unit)	1.7	0.8
Permanent employee labor (labor unit)	0.3	0.6
Temporary labor (hours)	1507.0	1891.0
Environmental subsidies (e.g. AES) (%)	51.4	
Farm not transmitted or outside the family within 5 years (%)	10.0	
Production in addition to grape production		
Another type of production (%)	62.9	
Crops (%)	50.0	
Vegetable and/or fruits production (%)	12.9	
Cattle (%)	5.7	
Poultry and/or Hogs (%)	4.3	
Forestry (%)	4.3	
<i>Winegrowers characteristics</i>		
Age	51.1	12.7
Higher education (%)	57.1	
Main objective		
Increasing income (%)	31.4	
Balancing work and family life (%)	24.3	
Being healthy	21.4	
Farming while improving environment (%)	10.0	

4.3.2. Relationship between winegrowers and the cooperative

In the survey, few questions focus on the relationship between the winegrowers and their wine cooperative. We explore information exchange between the cooperative and its members about agricultural practices and training (Table 4.3). The survey results highlight strong ties between the winegrowers and the cooperative *Les Vignerons de Buzet*. Almost all winegrowers (94%) state that they exchange information about their agricultural practices with the cooperative several times a year, and nearly half of them (42%) report exchanging information several times

a month. These exchanges regarding practices between the cooperative and the winegrowers also encompass the environmental and social benefits of these practices. Beyond information exchange, there is also a normative dimension in the relation between the cooperative and winegrowers as 96% of winegrowers state that the cooperative assess their agricultural practices regarding environmental and social benefits.

With regard to training, winegrowers are generally satisfied with both the frequency and quality of the training they receive by the cooperative. This satisfaction is reflected in the fact that 60% of the winegrowers implement what they have learned in their vineyards.

Due to frequent interactions between the winegrowers and the cooperative through advisory services and training, the cooperative holds a privileged position for information transfer, especially regarding new agricultural practices. According to 90% of the surveyed winegrowers, the cooperative strategy is an important driver of their practices adoption.

Table 4.3. Descriptive statistics on the relationship between winegrowers and the cooperative

Variables	% of respondents
<i>Cooperative and information sharing</i>	
Cooperative advices about my practices several times a year	94.3
Cooperative advices about my practices several times a month	42.9
Environmental and social advantage of agricultural practices – discussion with the cooperative ^a	87.1
Environmental and social advantage of agricultural practices – evaluation by the cooperative ^a	95.7
<i>Cooperative and Training</i>	
Sufficient training opportunities ^a	94.3
Use of practices leaned during training ^a	60.0
Interesting issues ^a	78.6
<i>Cooperative and practices change</i>	
Cooperative strategy is an important driver of practices adoption ^a	90.0

^a Responses to the questions were given on a Likert scale (Strongly disagree, Disagree, Slightly disagree, Slightly agree, Agree, Strongly agree). Responses were coded as dummy variables taking the value 1 if winegrowers responded “slightly agree, agree, or strongly agree” and 0 otherwise.

4.3.3. The adoption of new practices by winegrowers and their perception of organic farming

We interviewed the winegrowers about their perception of organic farming. We also questioned them about their willingness to adopt new practices and the motivating factors. The results presented in Table 4.4 highlight that 73% of the winegrowers do not feel ready to adopt organic farming on their vineyards. However, for most of them, they cite that this is not due to a lack of access to advice and support (81%), neither a lack of skills and knowledge (64%).

Our survey reveals that one of the main obstacles to converting into organic farming is the technical aspect. Three-quarters of the winegrowers state that organic farming practices are challenging to implement, and efficient alternatives to synthetic chemical products are difficult to find. This result aligns with the more broad questions related to the adoption of new agricultural practices as winegrowers declare that technology (63%) and skilled labor availability (47%) are important drivers of the adoption of new practices. The second identified obstacle is the economic effect of organic farming: 74% of the winegrowers state that adopting this standard would negatively affect their profits. Farmers often view organic practices as riskier as compared to conventional methods due to an increased vulnerability in yield fluctuations resulting from restrictions on chemical pesticides and fertilizers usage (Gardebroek *et al.*, 2010; Knapp and van der Heijden, 2018). Risk perception for a majority of winegrowers is another additional barrier to adopting organic farming. While 70% of them declare liking to experiment with new practices, nearly 60% state that they do not enjoy testing risky solutions. The fourth identified barrier to convert to organic farming is the impact of this type of agriculture on the physical and mental workload, as well as the distribution of peak labor periods throughout the year. The latest identified barriers are social and normative factors. While 77% of the winegrowers declare that the well-established nature of an agricultural practice significantly influences its adoption, 63% of them admit to know few organic farmers. Additionally, nearly half of the winegrowers indicate that their neighboring farmers are concerned about the expansion of organic farming surfaces.

These results align with prior literature on factors influencing the adoption of organic farming (Dessart *et al.*, 2019). They reveal diverse perspectives among farmers regarding the adoption of new practices and highlight a heterogeneous perception of organic farming within our sample.

Table 4.4. Descriptive statistics on the adoption of new practices by winegrowers and their perception of organic farming

Variables	% of respondents
<i>Important personal drivers of agricultural practices adoption</i>	
Be proud of his work ^b	98.6
Respect future generations ^b	92.9
Well-established practice ^b	77.1
Innovative practice ^b	61.4
<i>Important drivers of practices adoption</i>	
Cooperative strategy ^b	90.0
Farm succession project ^b	25.7
Change in public regulation ^b	78.6
Technology availability ^b	62.9
Skilled labor availability ^b	47.1
Financial difficulties ^b	47.1
Change in input price ^b	37.1
Change in output price ^b	65.7
New sales opportunities ^b	58.6
<i>Willingness to adopt new practices</i>	
Like to experiment new practices ^a	70.0
Do not like to change usual practices ^a	58.6
Like to test risky solutions ^a	41.4
Like to think for a long time before taking action ^a	80.0
Tendency to postpone investment decisions ^a	32.9
<i>Organic farming perception</i>	
No consensus on organic farming as good ^a	60.0
Few organic farmers known ^a	62.9
Neighborhood fear about neighboring plot organic conversion ^a	48.6
Efficient alternative to synthetic chemical product hard to find ^c	75.7
Organic practices hard to apply ^a	77.1
<i>Converting to organic farming</i>	
Being ready ^a	27.1
Access to advice and support ^a	81.4
Lack of skills and knowledge ^a	35.7
<i>Expected impact of organic conversion</i>	
Decreased profit ^d	74.3
Decreased production ^d	95.7
Increased workload ^e	98.6
Increased seasonal labor ^e	94.3
Increased labor physical strain ^e	82.9
Increased mental workload ^e	92.9
Decreased quality of family life ^d	67.1

^a Responses to the questions were given on a Likert scale (Strongly disagree, Disagree, Slightly disagree, Slightly agree, Agree, Strongly agree). Responses were coded as dummy variables taking the value 1 if winegrowers responded “slightly agree, agree, or strongly agree” and 0 otherwise.

^b Responses to the questions were given on a Likert scale (Not at all important, Slightly important, Important, Very important). Responses were coded as dummy variables taking the value 1 if winegrowers responded “important or very important” and 0 otherwise.

^c Responses to the questions were given on a Likert scale (Very difficult, Difficult, I don't know, Easy, Very easy). Responses were coded as dummy variables taking the value 1 if winegrowers responded "very difficult or difficult" and 0 otherwise.

^d Responses to the questions were given on a Likert scale (High decrease, Slight decrease, No change, Slight increase, High increase). Responses were coded as dummy variables taking the value 1 if winegrowers responded "high decrease or slight decrease" and 0 otherwise.

^e Responses to the questions were given on a Likert scale (High decrease, Slight decrease, No change, Slight increase, High increase). Responses were coded as dummy variables taking the value 1 if winegrowers responded "slight increase or high increase" and 0 otherwise.

4.4. Results

4.4.1. Winegrowers preferences for farming contract attributes

In order to support winegrowers in adopting organic farming, the cooperative aims to introduce new contracts that align with the expectations and preferences of winegrowers. The results of the four MXL models are presented in Table 4.5. All four models treat *environmental requirement* attribute levels as random parameters. In Model 2, we introduce an interaction between the levels of *environmental requirement* and a dummy variable (*like_risky_solutions*), which takes the value 1 when winegrowers indicate a preference for testing risky solutions⁵. In Model 3, the interaction occurs with the dummy variable (*organic_ready*), which takes the value 1 when winegrowers declare that they are ready to convert to organic farming⁶. Model 4 includes both interactions.

For all four models, the *payment* attribute coefficient is statistically significant and has the expected sign. Offering a 30% price premium on the base rate increases the probability of winegrowers subscribing to the contract with the cooperative. Moreover, when adding a compensation for yield reduction through a cooperative pooling fund or guaranteeing income per hectare increases the probability of contract adoption. It is not surprising that the attribute level guaranteeing income per hectare is significant and positive, as this contract attribute provides a high level of security for the winegrowers. Winegrowers show a preference for

⁵ The exact question asked to the winegrowers was: "To what extent does the statement 'I like to try solutions that are risky' describe your approach to managing your vineyard?" The possible responses were provided on a 6-level Likert scale (Strongly disagree, Disagree, Slightly disagree, Slightly agree, Agree, Strongly agree). The response was recoded into a dummy variable, taking the value 1 for winegrowers who responded Somewhat agree, Agree, or Completely agree, and 0 for those who chose otherwise.

⁶ The exact question asked to the winegrowers was: "Do you feel ready to convert your vineyard to organic farming within the next five years?" The possible responses were provided on a 6-level Likert scale (Strongly disagree, Disagree, Slightly disagree, Slightly agree, Agree, Strongly agree). The response was recoded into a dummy variable, taking the value 1 for winegrowers who responded Somewhat agree, Agree, or Completely agree, and 0 for those who chose otherwise.

contracts that include compensation for potential yield loss through a cooperative fund. It reflects their trust in their cooperative. However, as the agricultural cooperative is specialized, this pooling fund does not guarantee any production loss management when all members adopt organic production system. The solidarity among members is then not sufficient. The wine cooperative should then find external funds to offer this compensation scheme. Despite the concerns expressed about the impact of adopting organic farming on economic and labor organization aspects (see section 2.3.3), the levels of the *access to individual support* attribute are not significant and positive in our results. This suggests that winegrowers may not want the wine cooperative to interfere in their decisions regarding their farm management and that the cooperative's role is primarily intended to support vineyards in technical matters. Coefficients associated with the two levels of the attribute *environmental requirement* are both negative and significant. It suggests that requiring the implementation of organic practices negatively affects the probability of winegrowers adopting a contract different from their current one. We also observe it when the contract requires the joint adoption of organic farming practices and conservation agriculture. The standard deviations of the parameters are significant, indicating that there is unobserved preference heterogeneity among winegrowers regarding the attribute *environmental requirement*. We further explore this heterogeneity in models 2, 3 and 4 by introducing interaction terms. Results show that winegrowers who declare that they enjoy testing risky solutions and feel ready to convert to organic farming are more prone to accept a contract with environmental requirements. These results are aligned with earlier studies that have pointed out the relatively lower risk aversion of organic farmers compared to their conventional counterparts (Serra *et al.*, 2008; Gardebroek *et al.*, 2010; Läßle and Kelley, 2015).

While providing individualized contracts for each winegrower is not realistic, the cooperative may offer a range of contract options to allow them to better align with their own and individual preferences. We implement a latent class model which identifies segments of individuals with homogenous preferences. This approach helps to identify the winegrowers that are more likely to adopt contracts with environmental requirements and determine the optimal contractual conditions for such an adoption.

Table 4.5. Mixed logit models estimations

	(1)	(2)	(3)	(4)
Attributes and constant				
support_tech	<i>Ref.</i>	<i>Ref.</i>	<i>Ref.</i>	<i>Ref.</i>
support_tech-eco	-0.45*	-0.43	-0.42	-0.41
	(0.27)	(0.27)	(0.27)	(0.27)
support_tech-eco-orga	-0.53	-0.53	-0.53	-0.52
	(0.37)	(0.37)	(0.37)	(0.37)
area_100%	<i>Ref.</i>	<i>Ref.</i>	<i>Ref.</i>	<i>Ref.</i>
area_50%	-0.31	-0.29	-0.28	-0.27
	(0.24)	(0.24)	(0.24)	(0.24)
requirement_MQS	<i>Ref.</i>	<i>Ref.</i>	<i>Ref.</i>	<i>Ref.</i>
requirement_organic	-3.56***	-4.50***	-4.30***	-4.76***
	(0.65)	(0.93)	(0.74)	(0.84)
requirement_organic-CA	-4.77***	-5.55***	-5.78***	-6.14***
	(1.14)	(1.24)	(1.15)	(1.32)
payment_base	<i>Ref.</i>	<i>Ref.</i>	<i>Ref.</i>	<i>Ref.</i>
payment_base+30%	0.62**	0.66***	0.68***	0.69***
	(0.27)	(0.26)	(0.26)	(0.27)
compensation_annual-target	<i>Ref.</i>	<i>Ref.</i>	<i>Ref.</i>	<i>Ref.</i>
compensation_externalize	0.21	0.15	0.13	0.11
	(0.36)	(0.37)	(0.37)	(0.36)
compensation_coop-fund	0.97***	0.91***	0.89***	0.86***
	(0.33)	(0.34)	(0.34)	(0.34)
compensation_guaranty-ha	0.70**	0.68**	0.66*	0.64**
	(0.34)	(0.34)	(0.34)	(0.33)
compensation_multi-year-target	0.13	0.10	0.08	0.07
	(0.37)	(0.38)	(0.38)	(0.37)
Interactions				
requirement_MQS *		<i>Ref.</i>		<i>Ref.</i>
like_risky_solutions				
requirement_organic *		2.22**		1.74*
like_risky_solutions		(1.00)		(0.93)
requirement_organic-CA *		2.16**		1.63
like_risky_solutions		(1.09)		(1.13)
requirement_MQS * organic_ready			<i>Ref.</i>	<i>Ref.</i>
requirement_organic * organic_ready			2.29***	1.92**
			(0.89)	(0.93)
requirement_organic-CA *			3.75***	3.37***
organic_ready			(1.21)	(1.16)
Std. dev. of the parameters				
requirement_MQS	<i>Ref.</i>	<i>Ref.</i>	<i>Ref.</i>	<i>Ref.</i>
requirement_organic	-3.25***	-2.81***	-3.00***	-2.61***
	(0.74)	(0.52)	(0.62)	(0.49)
Requirement_organic-CA	-4.59***	-4.30***	-3.81***	-3.44***
	(1.31)	(1.16)	(0.87)	(0.72)
Log-likelihood	-301.96	-297.88	-294.70	-292.19
McFadden's pseudo-R ²	0.25	0.26	0.27	0.27
AIC	627.91	623.76	617.40	616.39
BIC	676.4	680.32	673.97	681.03
Number of observations	420	420	420	420
Estimated parameter	12	14	14	16

*, **, *** indicate significance at the 10%, 5% and 1% levels, respectively.

4.4.2. Identifying winegrowers likely to adopt contracts with environmental requirements

Results of the Latent Class model are presented in Table 4.6. We pinpoint a class that we refer to as *Organic lovers*. The likelihood of choosing a contract rises as the contract requires the implementation of organic practices, either exclusively or combined with conservation agriculture. For this group of winegrowers, the two components of the pricing formula also enhance the probability of contract adoption: the inclusion of a 30% premium tied to the base payment and the compensation for potential yield loss. Only the coefficient related to compensation by an external organization such as an insurance company does not significantly affect the probability of contract adoption. We identify a second group, labelled as *Reluctant to organic*. Both levels of the *environmental requirement* attribute negatively affect the probability of adopting a contract different from the current one. However, these winegrowers perceive as beneficial the alternative of contracting for only 50% of their vineyard surfaces. Within this group, the probability of adopting a new kind of contract is also increased by modifying the pricing formula; they value the 30% premium on the base price and the possibility of compensating potential yield losses with a guaranteed income per hectare. The last group that we identified differs from the previous one in that, apart from being reluctant to contracts with environmental requirements, they also display reluctance towards the option of contracting for only 50% of their vineyards and receiving individualized economic and organizational support from the cooperative. We refer to this class of winegrowers as *Reluctant to change*. Similar to the winegrowers in the other two groups, the 30% premium on the base price increases the likelihood of adopting a new type of contract. They are also receptive to the possibility of using a cooperative pooling fund to mitigate potential yield losses. The preferences of the winegrowers in this last class support the hypothesis we presented in the previous section while examining the mixed logit model: although these winegrowers have confidence in the cooperative, they do not wish for the cooperative to intrude into their economic and organizational farm management.

The groups *Reluctant to change* gather most of the winegrowers of the cooperative, accounting for 61% of the members. In contrast, *Reluctant to organic* and *Organic lovers* groups comprise 13% and 26% of the cooperative's members, respectively. Resistance to change is linked to the status quo bias which is described as people preferring to keep their current practices due to the perception that any modification represents a loss (Samuelson and Zeckhauser, 1988; Dessart

et al., 2019). The large number of winegrowers falling into this category is consistent with the results from literature on DCE conducted on agri-environmental policies, which show that a significant share of farmers tend to reject change systematically (Barreiro-Hurle *et al.*, 2018).

We investigate the winegrowers' characteristics that are associated with a higher likelihood of adopting contracts that require organic farming in Table 4.7. We find that farmers belonging to the group *Reluctant to organic* are, on average, more educated. At first, this result may seem surprising. However, we took a closer examination on the type of higher education that winegrowers pursued. It revealed that those farmers predominantly had agricultural studies and they are 47. It is noteworthy that a majority of those winegrowers completed their agricultural studies during a period when conventional practices were predominantly taught. This might explain the reason why farmers that are reluctant to organic farming are on average more educated.

Our findings emphasize differences between winegrowers in the Organic Lovers group and those in the other two groups. A majority of *Organic lovers* (67%) express readiness to convert their vineyards to organic farming, and less than half of them (44%) anticipate a decrease in their profits as a consequence. Nevertheless, similar to winegrowers in the other groups, *Organic lovers* also believe that this transition would have an impact on their production, workload, and labor organization. Considering that adopting organic farming might result in greater labor demands and a shift in its annual allocation is in line with previous finding (Midler *et al.*, 2019). The *Organic lovers* also stand out in terms of their willingness to adopt new practices. The majority of them declare that they enjoy experimenting new practices (100%), testing risky solutions (78%), and are ready to modify usual practices (78%). Furthermore, unlike the other two groups, none of them admits having a habit of delaying investments, and a larger proportion of them claim to make decisions promptly. These characteristics may reflect a lower perception of risk among winegrowers belonging to the Organic lovers group. Previous studies have highlighted that organic farmers tend to be less risk-averse than conventional farmers (Serra *et al.*, 2008; Gardebroek *et al.*, 2010; Läpple and Kelley, 2015) and have a lower perception of risk (Flaten *et al.*, 2005). On the contrary, risk perception and aversion to risk can hinder the adoption of environmental practices (Trujillo-Barrera *et al.*, 2016; Chèze *et al.*, 2020; Lefebvre *et al.*, 2020). Additionally, it is worth noting that their market environment highly influences the practices of the *Organic lovers'* winegrowers. They unanimously state that changes in the output price of and new sales opportunities are significant drivers when deciding to change agricultural practices.

The main difference between the *Reluctant to Organic* group and the *Reluctant to change* group lies in the question related to the burden of modifying usual practices. We find that a larger share of winegrowers in the *Organic reluctant* group declares that they do not like changing usual practices. This is a major barrier to the adoption of organic farming for farmers belonging to this group.

The reluctance to change their practices may be attributed to their past experiences with financial constraints and difficulties in hiring skilled labor. In fact, 78% of the winegrowers belonging to the "Reluctant to Organic" group had to change their agricultural practices due to a lack of qualified labor. This may make them more hesitant to adopt organic farming, which is known to require an increased level of skilled labor. Additionally, 67% of the *Reluctant to Organic* winegrowers had to change their practices in the past due to financial difficulties. It is worth noting the dichotomous positioning of the winegrowers who faced financial challenges. Those we classify as *Reluctant to Organic* do not foresee adopting organic farming as they fear it might lead to a decrease in profit. Conversely, the *Organic Lovers* seem to rely on the financial benefits of organic production, driven by the price premium, to address their financial difficulties.

Despite the cooperative's planned changes in contract attributes to support the adoption of organic farming, these incentives alone may not be sufficient to convince 87% of cooperative members to adopt contracts with more environmental requirements. These findings hold true in the short term; over time, the reluctant winegrowers might adjust their contract attribute preferences. If they witness positive outcomes among their peers who have opted for organic farming, they could reassess their risk perception. Furthermore, the decisions to adopt organic farming could be influenced by other farmers' actions, known as the descriptive norm effect (Dessart *et al.*, 2019). This appears even more plausible as 77% of the winegrowers in our sample state that the widespread adoption of a practice significantly affects the adoption of new practices. Upon reaching a certain adoption threshold of organic farming within the cooperative, it could encourage others to follow.

In our sample, 15 winegrowers consistently chose the *status quo* contract. The literature refers to them as protesters. The literature extensively discusses the challenges of identifying genuine protesters from individuals with a high willingness to accept, and managing protesters in data analysis, as this can influence willingness to accept measures (Villanueva *et al.*, 2017; Mariel *et al.*, 2021). To date, the question remains open. In our analysis, identifying protesters is less critical as we do not intend to measure willingness to accept. Moreover, we do not exclude

protestors from our analysis because, as members of the cooperative, they provide valuable insights into winegrowers' preferences regarding contracts. To validate our findings, we conduct a robustness check presented in the appendix (Tables 4A.1 and 4A.2), where we estimate the models without protestors. Our conclusions remain robust even after excluding protestors.

Table 4.6. Latent class model estimations

	Reluctant to change		Reluctant to organic		Organic lovers	
	Coef.	s.e.	Coef.	s.e.	Coef.	s.e.
Attributes and constant						
support_tech	<i>Ref.</i>		<i>Ref.</i>		<i>Ref.</i>	
support_tech-eco	-1.18***	0.48	0.73	0.77	0.41	0.38
support_tech-eco-orga	-1.35**	0.62	1.36	1.31	-2.01	1.62
area_100%	<i>Ref.</i>		<i>Ref.</i>		<i>Ref.</i>	
area_50%	-1.33***	0.45	1.03**	0.47	0.51	0.35
requirement_MQS	<i>Ref.</i>		<i>Ref.</i>		<i>Ref.</i>	
requirement_organic	-3.98***	0.71	-4.42***	0.80	4.34***	1.20
requirement_organic-CA	-4.53***	0.71	-4.73***	1.23	5.76***	1.10
payment_base	<i>Ref.</i>		<i>Ref.</i>		<i>Ref.</i>	
payment_base+30%	0.77**	0.40	1.34**	0.64	3.78**	1.60
compensation_annual-target	<i>Ref.</i>		<i>Ref.</i>		<i>Ref.</i>	
compensation_externalize	-0.06	0.81	1.00	0.87	0.48	0.54
compensation_coop-fund	1.68***	0.62	0.52	0.66	2.01***	0.57
compensation_guaranty-ha	0.91	0.57	2.76***	1.00	1.92***	0.53
compensation_multi-year-target	0.64	0.73	1.47	0.92	1.36***	0.46
Share (%)	61.43		25.71		12.86	
Log-likelihood	-253.83					
McFadden's pseudo-R ²	0.33					
AIC	571.65					
BIC	700.94					
Number of observations	420					

*, **, *** indicate significance at the 10%, 5% and 1% levels, respectively.

Table 4.7. Latent class model characteristics

Variables	% of respondents		
	Reluctant to change	Reluctant to organic	Organic lovers
<i>Winegrowers' sociodemographic characteristics</i>			
Age (years)			
< 40	14.0	33.3	22.2
[40 ; 60]	62.8	55.6	44.4
> 60	23.3	11.1	33.3
Education	β	β	
Primary education	2.3	11.1	0.0
Short-cycle secondary education	55.8	16.7	44.4
Long-cycle secondary education – agricultural	14.0	0.0	22.2
Long-cycle secondary education – non-agricultural	2.3	5.6	0.0
Higher education – agricultural	16.3	55.6	33.3
Higher education – non-agricultural	9.3	11.1	0.0
<i>Farms characteristics</i>			
Utilized agricultural area			
< 20	20.9	11.1	11.1
[20 ; 50]	37.2	22.2	44.4
]50 ; 100]	25.6	33.3	22.2
> 100	16.3	33.3	22.2
Another type of production in addition to viticulture	62.8	72.2	44.4
<i>Important personal drivers of practices adoption</i>			
Pride of work ^b	97.7	100.0	100.0
Respects future generations ^b	95.3	83.3	100.0
Well-established practice ^b	83.7	66.7	66.7
Innovative practice ^b	60.5	50.0	88.9
<i>Important drivers of practices adoption</i>			
Cooperative strategy ^b	86.0	94.4	100.0
Farm succession project ^b	20.9	38.9	22.2
Regulation change ^b	79.1	72.2	88.9
Technology availability ^b	60.5	61.1	77.8
Skilled labour availability ^b	34.9 β	77.8 β	44.4
Financial difficulties ^b	34.9 β	66.7 β	66.7
Input price change ^b	34.9	33.3	55.6
Product price change ^b	53.5 $\alpha\beta$	77.8 β	100.0 α
New sales opportunities ^b	46.5 α	66.7 γ	100.0 $\alpha\gamma$
<i>Willingness to adopt new practices</i>			
Like to experiment new practices ^a	62.8 α	72.2	100.0 α
Do not like to change usual practices ^a	53.5 β	88.9 $\beta\gamma$	22.2 γ
Like to test risky solutions ^a	34.9 α	38.9 γ	77.8 $\alpha\gamma$
Like to think for a long time before taking action ^a	88.4 α	72.2	55.6 α
Tendency to postpone investment decisions ^a	41.9 α	27.8	0.0 α
<i>Organic farming perception</i>			
No consensus on organic farming as good ^a	41.9	33.3	44.4
Few organic farmers known ^a	62.8	66.7	55.6
Neighbourhood fear neighbouring plot organic conversion ^a	46.5	44.4	66.7
Efficient alternative to synthetic product hard to find ^c	67.4	88.9	88.9
Organic practices hard to apply ^a	79.1	77.8	66.7
<i>Converting to organic farming</i>			
Being ready ^a	18.6 α	27.8 γ	66.7 $\alpha\gamma$

Access to advice and support ^a	79.1	83.3	88.9
Lack of skills and knowledge ^a	41.9	33.3	11.1
Expected impact of organic conversion			
Decreased profit ^d	81.4 ^α	72.2	44.4 ^α
Decreased production ^d	95.3	94.4	100.0
Increased workload ^e	97.7	100.0	100.0
Increased seasonal work ^e	93.0	94.4	100.0
Increased work physical strain ^e	86.0	77.8	77.8
Increased mental workload ^e	93.0	94.4	88.9
Decreased quality of family life ^d	65.1	77.8	55.6

α , β , γ indicate significance between groups on the performed Wilcoxon rank sum test and Fisher's exact test; α indicates significant differences between groups Reluctant to change and Organic lovers; β indicates significant differences between groups Reluctant to change and Reluctant to organic; γ indicates significant differences between groups Reluctant to organic and Organic lovers

^a Responses to the questions were given on a Likert scale (Strongly disagree, Disagree, Slightly disagree, Slightly agree, Agree, Strongly agree). Responses were coded as dummy variables taking the value 1 if winegrowers responded "slightly agree, agree, or strongly agree" and 0 otherwise.

^b Responses to the questions were given on a Likert scale (Not at all important, Slightly important, Important, Very important). Responses were coded as dummy variables taking the value 1 if winegrowers responded "important or very important" and 0 otherwise.

^c Responses to the questions were given on a Likert scale (Very difficult, Difficult, I don't know, Easy, Very easy). Responses were coded as dummy variables taking the value 1 if winegrowers responded "very difficult or difficult" and 0 otherwise.

^d Responses to the questions were given on a Likert scale (High decrease, Slight decrease, No change, Slight increase, High increase). Responses were coded as dummy variables taking the value 1 if winegrowers responded "high decrease or slight decrease" and 0 otherwise.

^e Responses to the questions were given on a Likert scale (High decrease, Slight decrease, No change, Slight increase, High increase). Responses were coded as dummy variables taking the value 1 if winegrowers responded "slight increase or high increase" and 0 otherwise.

4.5. Conclusion

In this paper, we examine the role that a cooperative can play through contracting to increase the adoption of organic farming among winegrowers. The role of the cooperative is particularly important, as it is the only stakeholder making wine within the PDO and therefore the unique purchaser of grape in the territory. By actively encouraging winegrowers to adopt environmental practices, it can ensure spatial continuity in practices adoption, addressing a common criticism often directed at agri-environmental policies (Westerink *et al.*, 2015; Westerink *et al.*, 2017). The cooperative's commitment to engaging all its members in the organic farming is driven by its aspiration to differentiate more broadly the collective brand of the *Buzet* PDO by incorporating environmental requirements.

Our study reveals that winegrowers are more inclined to adopt contracts where the base price is complemented by a 30% premium and where compensation for yield loss is included. The preferred forms of compensation are income guarantee per hectare and the cooperative fund.

Winegrowers have heterogeneous preferences regarding the inclusion of environmental requirements, such as organic and conservation farming, within the farming contracts. Winegrowers who declare that they enjoy testing risky solutions and feel ready to convert to organic farming are more willing to adopt a contract where organic farming is a requirement.

A latent class model allowed us to identify three groups of winegrowers with homogeneous preferences. The majority of winegrowers of the cooperative, 61%, are reluctant to change and merely 13% of the winegrowers would consider shifting to organic farming in their vineyards. *Organic lovers* winegrowers stand out from the other two groups regarding their perception of organic farming and willingness to adopt new practices. Most of them feel ready to convert their vineyards to organic farming and do not anticipate a decrease in their profits as a consequence. The majority of them declare that they enjoy experimenting new practices, testing risky solutions, are open to modifying usual practices, make decisions promptly and do not delay investments.

Overall, this study suggests that while cooperatives' farming contracts can be a potential instrument to increase uptake of organic farming, they will need to be complemented, at least in the short-term, with other tools and more public policies in order to scale the uptake of organic farming to a larger share of winegrowers. However, despite the declared ambitious political ambition in the Green Deal to reach 25% of agricultural land under organic farming by 2030, the 2023-2027 Common Agricultural Policy (CAP) program eliminates support for maintenance of organic farming. It will be partially compensated by a 36% increase of the budget allocated to conversion subsidies but given the allocated resources, the French Court of Auditors doubts the achievement of the stated objective (Cour des comptes, 2022).

Over the long term, we identify two potential drivers that could promote the adoption of organic farming among winegrowers. The first factor relates to winegrowers potentially modifying their contract preferences if they witness positive outcomes experienced by their fellow winegrowers who have already adopted organic farming. Moreover, if the adoption of organic farming reaches a critical mass within the cooperative, the influence of social norms could encourage reluctant winegrowers to adopt organic farming. The second long-term driver relies on market incentives. In the context of the wine sector, the organic segment is expanding, sales of organic wines increased by 2.2% from 2021 to 2022, despite a 0.4% decline in overall organic product consumption (Agence Bio, 2023). The adoption of organic agriculture could become a market access requirement in the future. This mechanism is strengthened by the fact that PDO is a

collective brand, necessitating the commitment of all its members to ensure its persistence in the market.

The adoption of environmental practices is of significant concern for cooperatives situated on a PDO territory. If not through the adoption of the organic farming standard by its members, it could be achieved by incorporating environmental practices into the PDO specification. The proposal for regulation on EU geographical indication states that “producers of geographical indications should be encouraged to adhere to sustainability standards that are more stringent than the mandatory ones, encompassing environmental, social and economic objectives.” If the regulation is approved by the European Parliament in October 2023, “specific requirements should be set out in the product specification or in a separate initiative”⁷.

Our findings are particularly valuable for the partner cooperative to designing new contracts. Additionally, they contribute to a broader understanding of the winegrowers' preferences concerning attributes that can influence their decisions regarding contract adoption. However, the external validity of the results might be limited due to the studied sample. Our findings should not be generalized to varying production, cultural or winegrower-cooperative relationship scenarios. Unlike policy-oriented studies that frequently aim for nationwide application, our study was designed to address a specific contractual issue within a specific sector.

Five different attributes compose the choice set of the DCE. Although winegrowers are very familiar with the attributes of the contract, it is likely that not all winegrowers consider the attributes with the same level of importance. For instance, we can imagine that attributes like *requirements imposed for the contracted area* and *payment* carry more weight in the winegrowers' decision-making process than the type of *individual support* offered to them. Some winegrowers may even consider only certain attributes when making their choices, which is referred to as Non-Attendance Attribute (NAA). As ignoring NAA impact model fits (Campbell *et al.*, 2008; Carlsson *et al.*, 2010), it would be valuable, as a robustness check in a future version of this paper, to identify possible NAA behavior by estimating analytical models.

⁷ Amendments adopted by the European Parliament on 1 June 2023 on the proposal for a regulation of the European Parliament and of the Council on European Union geographical indications for wine, spirit drinks and agricultural products, and quality schemes for agricultural products, amending Regulations (EU) No 1308/2013, (EU) 2017/1001 and (EU) 2019/787 and repealing Regulation (EU) No 1151/2012 (COM(2022)0134 – C9-0130/2022–2022/0089(COD)) https://www.europarl.europa.eu/doceo/document/TA-9-2023-0210_EN.pdf

4.6. Appendix













Attributes	Contract A	Contract B	Contract C
Access to individual support	 <p>Techno-economic and labor organization</p>	 <p>Technical</p>	 <p>Technical</p>
Farm area contracted	 <p>100%</p>	 <p>50%</p>	 <p>100%</p>
Environmental requirement	 <p>Organic farming and conservation agriculture</p>	 <p>Organic farming</p>	 <p>HEV</p>
Payment	<p>€ + 30%</p> <p>Base rate + 30%</p>	<p>€</p> <p>Base rate</p>	<p>€</p> <p>Base rate</p>
Compensation for yield reduction	 <p>Externalized</p>	 <p>Multi-year yield target</p>	 <p>Annual yield target</p>

Figure 4A.1. Choice Set

Table 4A.1. Mixed logit models estimations without potential protesters

	(1)	(2)	(3)	(4)
Attributes and constant				
support_tech	<i>Ref.</i>	<i>Ref.</i>	<i>Ref.</i>	<i>Ref.</i>
support_tech-eco	-0.35 (0.29)	-0.32 (0.29)	-0.31 (0.28)	-0.31 (0.29)
support_tech-eco-orga	-0.37 (0.47)	-0.36 (0.47)	-0.34 (0.46)	-0.34 (0.47)
area_100%	<i>Ref.</i>	<i>Ref.</i>	<i>Ref.</i>	<i>Ref.</i>
area_50%	0.00 (0.25)	0.02 (0.25)	0.02 (0.25)	0.01 (0.24)
requirement_MQS	<i>Ref.</i>	<i>Ref.</i>	<i>Ref.</i>	<i>Ref.</i>
requirement_organic	-3.39*** (0.65)	-4.37*** (0.91)	-4.02*** (0.73)	-4.55*** (0.89)
requirement_organic-CA	-4.23*** (1.15)	-5.59*** (1.66)	-5.37*** (1.10)	-5.94*** (1.38)
payment_base	<i>Ref.</i>	<i>Ref.</i>	<i>Ref.</i>	<i>Ref.</i>
payment_base+30%	0.77** (0.32)	0.82*** (0.32)	0.82*** (0.31)	0.81*** (0.31)
compensation_annual-target	<i>Ref.</i>	<i>Ref.</i>	<i>Ref.</i>	<i>Ref.</i>
compensation_externalize	0.33 (0.39)	0.26 (0.39)	0.27 (0.38)	0.27 (0.39)
compensation_coop-fund	1.36*** (0.38)	1.31*** (0.39)	1.27*** (0.37)	1.29*** (0.39)
compensation_guaranty-ha	1.20*** (0.38)	1.19*** (0.37)	1.18*** (0.37)	1.18*** (0.36)
compensation_multi-year-target	0.51 (0.39)	0.47 (0.39)	0.46 (0.39)	0.47 (0.39)
Interactions				
requirement_MQS *		<i>Ref.</i>		<i>Ref.</i>
like_risky_solutions				
requirement_organic *		2.45** (1.06)		2.16* (1.19)
like_risky_solutions				
requirement_organic-CA *		3.49** (1.67)		2.03 (1.33)
like_risky_solutions				
requirement_MQS * organic_ready			<i>Ref.</i>	<i>Ref.</i>
requirement_organic * organic_ready			2.35*** (1.13)	1.63 (0.93)
requirement_organic-CA * organic_ready			4.36*** (1.37)	4.17*** (1.45)
Std. dev. of the parameters				
requirement_MQS	<i>Ref.</i>	<i>Ref.</i>	<i>Ref.</i>	<i>Ref.</i>
requirement_organic	-2.75*** (0.59)	2.61*** (0.56)	-2.61*** (0.58)	2.39*** (0.72)
Requirement_organic-CA	-4.21*** (1.07)	-4.01*** (1.27)	-3.47*** (1.12)	-3.34*** (0.98)
Log-likelihood	-245.78	-240.07	-237.16	-233.95
McFadden's pseudo-R ²	0.28	0.29	0.30	0.30
AIC	515.55	508.14	502.31	499.91
BIC	561.14	561.33	555.50	560.69
Number of observations	330	330	330	330
Estimated parameter	12	14	14	16

*, **, *** indicate significance at the 10%, 5% and 1% levels, respectively.

Table 4A.2. Latent class model estimations without potential protesters

	Reluctant to change		Reluctant to organic		Organic lovers	
	Coef.	s.e.	Coef.	s.e.	Coef.	s.e.
Attributes and constant						
support_tech	<i>Ref.</i>		<i>Ref.</i>		<i>Ref.</i>	
support_tech-eco	-1.04**	0.58	1.01***	0.59	0.41	0.38
support_tech-eco-orga	-1.74**	0.85	1.69	1.26	-2.01	1.62
area_100%	<i>Ref.</i>		<i>Ref.</i>		<i>Ref.</i>	
area_50%	-0.63***	0.50	1.02**	0.51	0.51	0.34
requirement_MQS	<i>Ref.</i>		<i>Ref.</i>		<i>Ref.</i>	
requirement_organic	-4.11***	0.58	-4.38***	0.95	4.34***	1.20
requirement_organic-CA	-5.07***	0.87	-4.88***	1.36	5.76***	1.10
payment_base	<i>Ref.</i>		<i>Ref.</i>		<i>Ref.</i>	
payment_base+30%	1.29***	0.51	1.20**	0.65	3.79**	1.60
compensation_annual-target	<i>Ref.</i>		<i>Ref.</i>		<i>Ref.</i>	
compensation_externalize	-0.26	0.89	1.20	0.80	0.48	0.54
compensation_coop-fund	2.19***	0.81	0.50	0.84	2.00***	0.57
compensation_guaranty-ha	1.27*	0.71	2.95***	1.06	1.92***	0.53
compensation_multi-year-target	1.13	0.73	1.70	1.14	1.35***	0.46
Share (%)	57.53		26.37		12.86	
Log-likelihood	-211.40					
McFadden's pseudo-R ²	0.33					
AIC	486.80					
BIC	608.38					
Number of observations	330					

*, **, *** indicate significance at the 10%, 5% and 1% levels, respectively.

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Chapter 5. The implementation of the new Common Agricultural Policy in France will not be environmentally ambitious

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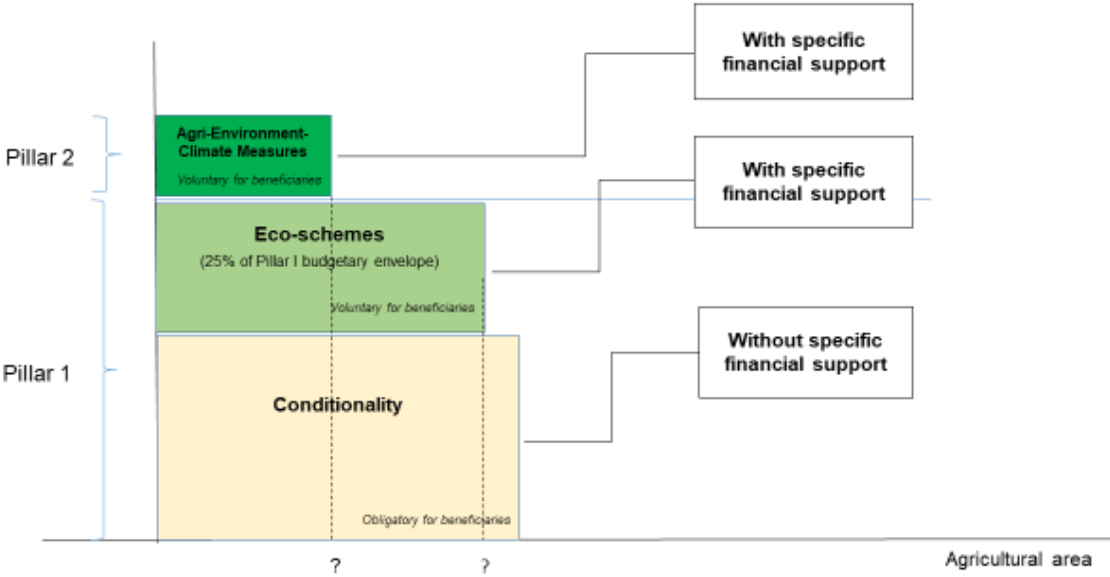
*The present version has been submitted to the *Journal of Environmental Planning and Management* in July 2023 and is under revision.*

5.1. Introduction

Agriculture in the European Union (EU) is not environmentally sustainable. Several indicators show that its environmental footprint has worsened over the last decades (Guyomard *et al.*, 2020). Despite prioritizing protection of the environment and progressively integrating regulatory and incentive environmental instruments, the successive reforms of the Common Agricultural Policy (CAP) have failed to date to put European agriculture on the right track (Navarro and López-Bao, 2018; Pe'er *et al.*, 2019; Dupraz and Guyomard, 2019). It is therefore appropriate that the 2023-2027 CAP includes climate change mitigation and adaptation, environmental care, and the preservation of biodiversity and landscapes as key objectives for this policy (European Commission, 2017).

To this end, the new CAP agreed in June 2021 defines a new green architecture (GA) based on three environmental instruments (Figure 5.1). Conditionality requires that farmers respect a set of statutory and management requirements related to health, environment, and animal welfare, and maintain land in good agricultural and environmental conditions (GAEC) in order to receive income support direct payments. Conditionality encompasses the three conditions of the so-called green payment of the previous CAP that has been highly criticized for its very low environmental effectiveness (European Court of Auditors, 2017). These conditions aim at maintaining permanent grasslands at the national or regional level (depending on the country), diversifying annual crops at the farm level, and preserving ecological focus areas at the farm level. Ecological focus areas include not only non-productive elements (such as hedges or fallows) but also some productive land uses (such as nitrogen-fixing crops, catch crops, or cover crops) with, however, lower weightings. Agri-environment-climate measures (AECMs) are voluntary multi-annual contracts that compensate farmers for the additional costs induced by the use of more environmentally friendly agricultural practices. Most AECMs are more geographically targeted than conditionality. However, they suffer from drawbacks that weaken their environmental effectiveness. These drawbacks are linked in particular to low budgetary endowments, low payments per hectare (ha), the adoption by farmers of the simplest but least ambitious measures from an environmental point of view, and the spatial discontinuity of good farming practices and high-diversity landscape features because of the involvement of an insufficient number of contiguous farms (Cullen *et al.*, 2018; Hasler *et al.*, 2022). These drawbacks largely remain in the 2023-2027 CAP (Guyomard *et al.*, 2020, 2023). Unlike conditionality and AECMs, the third instrument of the eco-scheme is novel. This voluntary instrument aims at rewarding farmers who are already managing land in an environmentally

friendly way and incentivizing other farmers to change their farming practices. Although the European legal texts introduce the possibility of granting eco-scheme payments on a multi-year basis, member states (MSs) have chosen to pay in the form of annual payments. The second novelty of the 2023-2027 CAP is indeed its governance through a new delivery model that gives MSs considerable leeway to design instruments and allocate their budgetary envelope between the instruments (European Court of Auditors, 2018). This means that assessing the environmental ambition of the 2023-2027 CAP requires a country-by-country approach centered on the eco-scheme of the CAP national strategic plan (NSP) of each MS (Runge *et al.*, 2022; Latacz-Lohmann *et al.*, 2022).



Source: Adapted from Guyomard *et al.* (2023). Pillar 1 includes income support aids and market intervention measures. It is fully funded by the European budget. Pillar 2 includes measures targeting a wide set of disparate objectives such as environmental protection (through AECMs), risk management, investment support, or support for farmers in less-favored areas. Pillar 2 is co-financed by national/regional budgets.

Figure 5. 1 The green architecture of the 2023-2027 Common Agricultural Policy

While many research studies have made recommendations for delivering environment action through the 2023-2027 CAP or have qualitatively evaluated its environmental ambition (Lampkin *et al.*, 2020; Guyomard *et al.*, 2020; Hasler *et al.*, 2022; Pe’er *et al.*, 2022; Guyomard *et al.*, 2023), there is no quantitative assessment of the CAP agreement reached in June 2021. This can be explained by the difficulties of *ex ante* assessments “given data, indicators, and integrated modeling frameworks that are currently available” (Guyomard *et al.*, 2023). This can also be explained by the incompleteness of the June 2021 European agreement since many implementing decisions are the responsibility of MSs through their respective NSP. Even

though draft NSPs were proposed during the second half of 2021 and the first months of 2022, the final versions of these NSPs were only approved by the European Commission at the very end of 2022. In their analysis of 15 draft eco-schemes as of January/February 2022, Runge *et al.* (2022) highlighted that “the level of environmental ambition may be not high” and that “the majority of the eco-scheme measures mirror existing schemes”. Environmental non-governmental organizations were even more critical of these drafts when they concluded that “18 out of 23 plans score only poor or very poor across the different [environmental] dimensions, indicating that the overwhelming majority of NSPs will fall short of what has been promised with regards to environmental and climate objectives” (European Environmental Bureau – EEB – and BirdLife International, 2022).

In France, a draft version of the NSP was submitted in December 2021. This first draft has been criticized as being insufficiently ambitious from an environment point of view (French Environmental Authority, 2021; European Commission, 2022). In July 2022, France submitted a revised version of its NSP that was approved without further changes by the European Commission in August 2022 (Ministry of Agriculture and Food Sovereignty – MASA –, 2022a). Since the two environmental instruments of conditionality and AECMs are only marginally improved relative to the previous policy (Guyomard *et al.*, 2023), the environmental ambition of the French NSP can be summed up as that of the French eco-scheme in a context where the annual budget allocated to the eco-scheme is substantial, that is: €1.68 billion (B) out of a total CAP budget of €7.83B. By comparison, the annual budget allocated to AECMs is €260 million (M), which represents an increase of €10M only with respect to the previous period (MASA, 2022a).

This paper aims at examining the environmental ambition of the French eco-scheme by assessing the number of farmers who would have access to either the standard level of the scheme or the superior level without changing their farming practices. The analysis is carried out for different farming specializations based on individual data of the French Farm Accountancy Data Network (FADN), which makes it possible to evaluate to what extent the eco-scheme constraint is more binding for some farm types (defined on the basis of the main production) than for others. The second objective of the paper is to characterize farms according to the level of the eco-scheme they would reach (no access, standard level only, superior level). In this way, we seek notably to understand the steps required to reach the superior level from the standard level.

The paper is organized as follows. Section 2 presents the three access paths to the French eco-scheme. Section 3 explains how we assessed whether a farm has access to one level of the eco-scheme for each access path. Results are displayed in Section 4 and discussed in Section 5.

5.2. The French eco-scheme

Three non-cumulative paths can be used to access the French eco-scheme; these are: i) the path of agro-ecological practices; ii) the path of environmental certification; and iii) the path of biodiversity friendly elements (MASA, 2022a). While both the practice and biodiversity paths are based on criteria that go beyond those of corresponding requirements of conditionality, the environmental certification path is based on two pre-existing environmental certifications; namely, the high environmental value (HEV) label and the organic farming label. For conventional farms, each access path includes two requirement levels; these are: a standard level giving entitlement to a payment of around €60/ha, and a superior level giving entitlement to a higher payment of around €80/ha for farmers involved in more ambitious ecological practices. The scheme includes a specific level for organic farmers with a higher payment of €110/ha. The scheme also encompasses a “hedge” bonus of €7/ha that can be cumulated with the first two access paths and requires that hedges cover at least 6% of agricultural area (and 6% of arable cropland area when applicable). The three access paths are summarized in Table 5.1 and detailed in Appendix 1.

Table 5.1. The three access paths to the French eco-scheme of the CAP

	Agro-ecological practices			Environmental certification	Biodiversity friendly elements (BFE)
	Diversity of arable crops	No tillage of permanent grasslands (PG)	Inter-row cover of perennial crops		
Standard level (~€60 per ha) ¹	4 points	Share of PG $\geq 80\%$ ²	Cover $\geq 75\%$ ³	At least 10 points for one component of the HEV certification ⁴	Share of BFE $\geq 7\%$ ⁵
Superior level (~€80 per ha) ¹	5 points or more	Share of PG $\geq 90\%$	Cover $\geq 95\%$	10 points or more on each component of the HEV certification	Share of BFE $\geq 10\%$
Organic level (~€110 per ha) ¹				Organic farming certification	
Hedge bonus (€7 per ha)	At least 6% of hedges on the utilized agricultural area, with 6% on arable land areas when applicable. Necessity of a “hedge” certification attesting to their sustainable management				Non-cumulative

Source: Authors' elaboration based on the French NSP of August 31, 2022 (MASA, 2022a). 1: Payment levels are indicative. 2: Share of PG is the share of non-tilled permanent grasslands in total grasslands. 3: Cover is the share of inter-rows of perennial crops that are covered by plants (grass or mulch); 4: See Table 5.2 for details of indicators and associated points for the three components of the environmental certification path (biodiversity, crop protection, and fertilization). 5: Share of BFE is the share of BFE in utilized agricultural area.

Requirements of the path of agro-ecological practices differ according to the plant cover of agricultural areas by differentiating between arable croplands, grasslands, and perennial croplands. For arable croplands, the objective is to favor crop diversity through a points system: the annual crop producer reaches the standard level when her/his score is equal to 4 points, and the superior level when her/his score is equal to 5 points or more. For grasslands, the objective is to maintain the ratio of non-tilled permanent grasslands of total permanent grasslands to at least 80% for the standard level and 90% or more for the superior level. For perennial croplands, the objective is to develop the inter-row coverage of perennial crops to at least 75% for the standard level and 95% or more for the superior level.

The path of biodiversity friendly elements aims at rewarding these because of their climate and biodiversity benefits (Pe'er *et al.*, 2016). Eligible elements are those that are accounted for in conditionality GAEC 8, including fallow lands but excluding nitrogen-fixing crops and catch crops that provide lower ecological benefits (MASA, 2022a). Access to the standard level requires that the admissible land area of the farm includes at least 7% of biodiversity friendly elements. Access to the superior level requires at least 10%.

The path of environmental certification is based on the HEV French label as defined in December 2016 (Ministry in charge of agriculture, 2016) for the year 2023 and as revised in November 2022 (MASA, 2022b) from 2024. The label distinguishes four components corresponding to i) biodiversity protection, ii) fertilization, iii) phytosanitary protection, and iv) irrigation. Each component is characterized by a variable number of requirements that makes it possible to earn a variable number of points. The basic level (called environmental certification 2+ or EC2+) requires that the farmer satisfies 16 minimal environmental conditions and obtains 10 points or more for at least one of the four dimensions. The superior level requires that he/she obtains 10 points or more for each of the four dimensions.

5.3. Assessing access to the eco-scheme: data and assumptions

The analysis is essentially based on farm data from the French FADN for the year 2020. Farms specialized in viticulture, arboriculture, and horticulture are excluded since they benefit very little from Pillar 1 CAP support (less than 2%) and as a consequence are very little concerned with the eco-scheme. The FADN sample includes 4,699 farms. Attention is focused on farm types 1500 (farms specialized in cereals, oilseeds and protein crops (COP)), 1600 (arable crops including COP and specialized crops such as sugar beet and potatoes), 4500 (dairy cattle), 4600 (beef cattle), 4813 (sheep and goats), and 6184 (mixed farming). In 2020, these six farming types represented 69% of French farms and 85% of agricultural utilized area (UAA). They received 88% of Pillar 1 budgetary support.

5.3.1. Access path of farming practices

It was possible to estimate the number of farms that would have access to both the standard and superior level through the practices access path for the arable crop diversity criterion based on FADN data on agricultural land uses. Section 1 of Appendix 1 details the assumptions used to retrieve the crop cover of the eco-scheme from the FADN database. The regulation specifies that the criterion for non-ploughed permanent grasslands must be calculated at the scale of the farm by dividing the number of hectares of non-ploughed permanent grasslands in year $n - 1$ by the number of hectares of permanent grasslands in year n . This way of calculating the criterion makes the constraint non-binding (Section 2 of Appendix 1). Since we have systematically minimized the number of farms reaching either the standard or superior level by

one of the three access paths, we assumed that all farms in our sample with more than 5% of their UAA cultivated with perennial crops (the threshold above which this indicator must be considered) do not access the eco-scheme through the practices access path.

5.3.2. Environmental certification access path

Table 5.2 displays the indicators that could be calculated for the three components of the environmental certification path (biodiversity, crop protection, and fertilization) as defined by the third version of 31 December 2016 of the HEV label. Given the information available, the indicators calculated make it possible to obtain a maximum score of 27 points for biodiversity (theoretical maximum score of 30 points), 20 points for crop protection (35), and 25 points for fertilization (30). We attributed a score of zero to all indicators that could not be calculated. This means that our results underestimate the number of points that a farm can obtain for each of these three components and therefore underestimate the number of farms that have access to the eco-scheme through the environmental certification path. This underestimation is, however, likely to be limited because one indicator only ('percentage of UAA covered by AECMs aimed at reducing the use of chemical pesticides') makes it possible to obtain a high number of points (10) but in practice concerns a very small number of farms.

Table 5.2. Indicators of the environmental certification access path for the three components of biodiversity, crop protection, and fertilization

Indicators	Maximum possible points	Indicators that could be calculated	Data bases	Main assumptions
Biodiversity				
% of agro-ecological infrastructures in utilized agricultural area (UAA)	10	Yes	FADN Hedges	Density of hedges at the farm level equal to that of the 'commune'
% of the dominant crop (excluding permanent grassland) in UAA	6	Yes	FADN	
Number of crop species grown	7	Yes	FADN	
Number of animal species kept	3	Yes	FADN	
Beehives on the farm	1	Yes	FADN	
Number of endangered varieties, breeds or species	3	No	-	0 point in simulations
Total of points for biodiversity	30	27		
Crop protection				
Herbicide treatment frequency index (TFI)	5	Yes	FADN PK2017*	Weighted average of regional TFIs for crops present in farm crop rotation
Non-herbicide TFI	5	Yes	FADN PK2017*	
% of untreated UAA	10	Yes	FADN	Areas in permanent grassland, fallow land, heathland, and rangeland were assumed untreated
% of UAA covered by alternatives to chemical pesticides	3	No	-	0 point in simulations
% of UAA covered by AECMs aimed at reducing the use of chemical pesticides	10	No	-	0 point in simulations
Application conditions of chemical pesticides	2	No		0 point in simulations
Total of points for crop protection	35	20		
Fertilization				
Nitrogen balance	10	Yes	FADN CASSIS-N	Nitrogen balance at the farm level equal to that of the 'canton'
Use of decision support tools	3	No	-	0 point in simulations
% of non-fertilized UAA	10	Yes	FADN	Areas in fallow land, heathland, and rangeland were assumed not fertilized
% of legumes (single crop) in UAA	2	Yes	FADN	
% of crop mixes with legumes in UAA	2	No	-	0 point in simulations
Fall soil cover	3	Yes	FADN NVA**	3 points for farms with 100% of permanent grasslands and for farms located in NVA (fall cover mandatory in NVA)
Total of points for fertilization	30	25		

Source: Authors' elaboration based on the version 3 of 31/12/2016 of the HEV certification label. *PK2017: 2017 national survey on cultural practices. **NVA: Nitrate vulnerable areas.

The calculation of several indicators of the environmental certification access path required the use of additional databases. The national database on hedges (Ministry in charge of the ecological transition and Ministry in charge of agriculture, 2020) provides the hedge density at the scale of French ‘*communes*’¹ and made it possible to calculate the biodiversity indicator related to the ‘share of agro-ecological infrastructures in total UAA’ by taking into account the infrastructure of hedges, permanent grasslands, moor- and range-lands, and fallow lands. We associated all farms in a given ‘*commune*’ with the hedge density of the ‘*commune*’. Other infrastructures theoretically included in the criterion were not available and therefore were not considered, implying that we underestimated the percentage of agro-ecological infrastructures. The calculation of herbicide and non-herbicide total frequency indexes (TFI) of the crop protection component was possible thanks to the 2017 survey on farming practices (Agreste, 2020). The farm nitrogen balance of the fertilization component was estimated based on simulation results derived from the model ‘CASSIS_N’ for the year 2015 (Poisvert *et al.*, 2016). This model provides estimates of nitrogen surpluses at the geographical scale of the French ‘*canton*’.² We assumed that the nitrogen balance of a farm in a given ‘*canton*’ was equal to that of the ‘*canton*’. We further assumed that farms with 100% of permanent grasslands or located in nitrate vulnerable areas (NVA) obtained 3 points for the indicator related to the ‘fall soil cover’. While the FADN directly provides information on permanent grasslands, the second group of farms was determined by matching the FADN database with the database on ‘*communes*’ in NVA in 2015 (EauFrance, 2015). Finally, the FADN database makes it possible to identify organic farms.

In order to determine the number of farms that have access to the eco-scheme through the environmental certification path, we made two final additional assumptions. Firstly, we assumed that all farms that used irrigation reached a score of at least 10 points on that fourth component of the certification access path. This hypothesis is based on the fact that corresponding farms can obtain 6 points for the indicator on ‘the detailed recording of irrigation practices’ and 4 points on the other indicators making it possible to collect 21 points in total. These other indicators are on ‘the use of support decision tools for irrigation’; ‘the percentage of UAA covered by the use of equipment that optimizes water use’; ‘the membership of a collective management approach’; ‘the percentage of UAA covered by water-saving agronomic

¹ ‘*Communes*’ are the smallest local administrative units in France. There were about 35,000 ‘*communes*’ in 2021.

² ‘*Cantons*’ are local administrative units that lie between ‘*communes*’ and NUTS3 regions. There are around 2,000 ‘*cantons*’.

practices’; and ‘the share of water withdrawals in low water periods’. Secondly, we assumed that all farms that meet the requirements of the environmental certification path are labelled. In practice, the farm must make an official application for the label and obtain approval after an audit by an independent certification body. This implicit labelling rests on the assumption that the income support granted through the eco-scheme is sufficient to motivate the farm to obtain the label.

5.3.3. Access path of biodiversity friendly elements

For the third access path of biodiversity friendly elements, it was possible to consider the eligible elements of hedges (again using the national database on hedges), fallows, and permanent grassland areas. The weighting coefficients of these elements differ from those of agro-ecological infrastructures of the biodiversity indicator of the environmental certification path (Table 5.3). Other biodiversity friendly elements could not be counted. The number of farms that could access the eco-scheme through the access path of biodiversity friendly elements is thus underestimated.

Table 5.3. Agro-ecological infrastructures of the biodiversity criterion of the environmental certification path and biodiversity friendly elements of the access path of biodiversity friendly elements included in the analysis with respective weighting factors

	Agro-ecological infrastructures (1)		Biodiversity friendly elements (1)	
	Included	Weighting factor	Included	Weighting factor
Hedges	Yes	1 lm* = 100 m ² of tes**	Yes	1 lm = 20 m ²
Fallows	Yes	1 ha = 1 ha of tea***	Yes	1 lm = 1 ha***
Permanent grassland, moorland, rangeland and mountain pasture in Natura 2000 areas	No	-	Yes	1 ha = 1.5 m ²

Source: Authors’ elaboration from MASA (2022a, 2023) and Ministry in charge of agriculture (2016). * lm = linear meter. ** tea = topographical equivalent area. *** Since it was not possible to distinguish honey, wildlife and flowering fallow areas from other fallow areas, we attributed the coefficient of 1 to all fallow areas even if coefficients of honey, wildlife and flowering fallow areas are higher in the regulations. (1) Agro-ecological infrastructures and biodiversity friendly elements include other items that could not be counted, notably unproductive buffer strips; aligning shafts; single trees; groups of trees; ponds; unshaped walls, and traditional walls.

5.4. Results

5.4.1. Assessment of the number of farms that would have access to the eco-regime without changing their current farming practices

Simulation results show that almost all farms (99.9%) would reach at least the standard level of the eco-scheme without changing their current farming practices and that 84.9% would reach the superior level (Table 5.4). While there are no access differences to the standard level between farms according to their productive specialization, livestock farms would more easily reach the superior level (91.4% for dairy cattle, 98.9% for sheep and goats, and 99.1% for beef cattle) than mixed farms (79.6%) and annual crop farms (66.2% for arable crops and 69.5% for COP). Agricultural areas in percentage terms of the different possible cases are almost the same suggesting that the farm size measured in hectares is not a differentiating access factor of the eco-scheme (Table 5.5).

Table 5.4. Percentages of farms that would have access to the French eco-scheme without changing their current farming practices

Agricultural specialization	Percentage of farms			
	Access to the eco-scheme (%)	Access / No access (%)		
		Superior level	Standard level only	No access
1500: COP	99.66	69.45	30.20	0.34
1600: Arable crops	99.78	66.23	33.55	0.22
4500: Dairy cattle	99.88	91.38	8.50	0.12
4600: Beef cattle	100	99.06	0.94	0.00
4813: Sheep and goats	100	98.92	1.07	0.00
6184: Mixed	99.86	79.55	20.30	0.14
Total*	99.85	84.85	15.00	0.15

Table 5.5. Utilized agricultural areas of farms depending on the access to the French eco-scheme for unchanged farming practices (in percent)

Agricultural specialization	Utilized agricultural area (%)			
	Access to the eco-scheme (%)	Access / No access (%)		
		Superior level	Standard level only	No access
1500: COP	99.77	71.32	28.45	0.23
1600: Arable crops	99.87	65.45	34.42	0.13
4500: Dairy cattle	99.84	92.16	7.68	0.16
4600: Beef cattle	100	99.09	0.91	0.00
4813: Sheep and goats	100	99.56	0.44	0.00
6184: Mixed	99.95	83.43	16.52	0.05
Total*	99.90	84.93	14.97	0.10

Source: Authors' calculation. *Figures for the total sample include all farm types except for viticulture, horticulture, and arboriculture; they therefore include farm types such as hog, poultry, or hog and poultry that are not detailed in the table.

Table 5.6 shows that the path of environmental certification allows almost all farms to reach at least the standard level (99.5%) without significant differences between farm types (from 99.7% for COP farms to 100% for both beef cattle and sheep and goat). Reaching at least the standard level though the access path of agro-ecological practices is hardly more difficult for livestock farms (99.5% for sheep and goats, 99.2% for beef cattle, and 95.3 % for dairy cattle). The practices access path reduces in a more substantial way the percentages of arable crop farms (81.5%), mixed farms (80.9%), and COP farms (74.3%) that would have access to at least the standard level. Accessing at least the standard level would be more difficult through the path of biodiversity friendly elements (64.6% for the whole sample), with large discrepancies according to farm specialization (from 34.0% for arable crops to 81.7% for beef cattle).

Table 5.7 shows that reaching the superior level without changing current practices is easier through the path of agro-ecological practices (71.7%) than through the two other access paths (31.7% for the environmental certification and 53.0% for biodiversity friendly elements). The three access paths increase by +13.3 percentage points the total number of farms that would reach the superior level through at least one of the three access paths (from a minimum of +1.4 percentage points for sheep and goats and to a maximum of +18.9 percentage points for COP). The complementarity between the three access paths can also be illustrated by noting that meeting the requirements of all three access paths would limit the percentages of eligible farms to 57.1% for the standard level and 17.4% for the superior level.

Table 5.6. Percentages of farms that would have access to the French eco-scheme by one of the three access paths without changing their current farming practices

Agricultural specialization	Access to at least the standard level (%)			
	One at the choice of the three access paths	Agricultural practices	Environmental certification	Biodiversity friendly elements
1500: COP	99.66	74.32	98.98	57.58
1600: Arable crops	99.78	81.51	98.71	33.98
4500: Dairy cattle	99.88	95.27	99.75	63.23
4600: Beef cattle	100	99.22	100	81.72
4813: Sheep and goats	100	99.46	100	79.78
6184: Mixed	99.86	80.93	99.59	55.52
Total*	99.85	86.42	99.53	64.55
	Access to the superior level (%)			
	One at the choice of the three access paths	Agricultural practices	Environmental certification	Biodiversity friendly elements
1500: COP	69.45	50.57	6.45	42.99
1600: Arable crops	66.23	60.43	6.88	24.94
4500: Dairy cattle	91.38	81.31	43.33	52.55
4600: Beef cattle	99.06	95.62	66.71	72.03
4813: Sheep and goats	98.92	97.57	64.42	70.62
6184: Mixed	79.55	63.81	19.06	41.99
Total*	84.85	71.72	31.69	52.99
	Access to the standard level only (%)			
	One at the choice of the three access paths	Agricultural practices	Environmental certification	Biodiversity friendly elements
1500: COP	30.20	23.76	92.53	14.59
1600: Arable crops	33.55	21.08	91.83	12.04
4500: Dairy cattle	8.50	13.96	56.43	10.68
4600: Beef cattle	0.94	3.59	33.28	9.69
4813: Sheep and goats	1.07	1.89	35.58	9.16
6184: Mixed	20.30	17.13	80.52	13.54
Total*	15.00	14.71	67.84	11.56

Source: Authors' calculation. *Figures for the total sample include all farm types except for viticulture, horticulture, and arboriculture; they therefore include farm types such as hog, poultry, or hog and poultry that are not detailed in the table.

Table 5.7. Complementarity of the three access paths: percentages of farms that would have access to the eco-scheme without changing their current farming practices by respecting the requirements of i) one of the access paths, ii) two paths jointly, and iii) three paths jointly

	Access (%) through						
	One of the paths			Two paths			Three paths
	AP	EC	BFE	AP & EC	AP & BFE	EC & BFE	AP, EC & BFE
At least the standard level	86.42	99.53	64.55	86.10	57.05	64.55	57.05
The superior level	71.72	31.69	52.99	29.60	41.71	18.49	17.43

Source: Authors' calculation. AP: Path of agro-ecological practices; EC: Path of environmental certification; BFE: Path of biodiversity friendly elements.

5.4.2. Comparison of farms at the superior vs standard level of the eco-scheme

In a first step, we compared the farms that would reach the superior level vs. the standard level only in terms of structural characteristics, economic results, technical performances, and environmental performances. We performed the exercise for farm types 1500 (COP), 1600 (arable crops), 4500 (dairy cattle), and 6184 (mixed farms). The comparison is irrelevant for types 4600 (beef cattle) and 4813 (sheep and goats) because of the very small number of holdings that would reach the standard level only in both types. The main lessons corresponding to statistically significant median differences can be summarized as follows (detailed results are available from the authors upon request).

Compared to farms that would reach the standard level only, farms at the superior level have more agricultural land area per unit of total labor (except for the farm type of arable crops), are more often located in disadvantaged areas, and receive more total aid per unit of UAA and more Pillar 2 aid per unit of UAA. Agricultural production (without aid) per unit of UAA and the consumption of raw materials per unit of UAA is lower at the superior level than at the standard only for the four farm types. The partial productivities of labor and land (with and without aid) are significantly lower at the superior level for the four farm types. The partial productivity of raw materials without aid is also lower at the superior level, except for arable crop farms for which there is no significant difference. Agricultural income before tax for both groups of farms

(superior vs. standard level) is not statistically different except for COP farms that have lower income in total, per ha of UAA and per unit of farm family labor at the superior level.

When environmental indicators are directly related to criteria used for constructing eco-scheme access indicators and scores, it is not surprising to find an improved environmental picture at the superior level. It is more interesting to note that both fertilizer and crop protection expenses per unit of UAA are significantly lower at the superior level than at the standard level. This last result suggests that there is a negative correlation between eco-scheme indicators/scores on the one hand and fertilizer and pesticide expenditures per hectare on the other hand. However, even if median differences were statistically different, it would not be possible to assess the improvement of the environmental state at the superior level from these indicators/scores since they are all based on practices and not on environmental results/impacts.

In a second step, we completed the descriptive statistical analysis by an econometric analysis where the classification at the superior level ($Y = 1$) vs. the standard level ($Y = 0$) was modeled through a Probit model: $P(Y = 1/X) = \Phi(X^T \beta)$ where P is the probability, Φ the cumulative distribution function of the standard normal distribution, β the vector of parameters to be estimated, and X the set of explanatory variables (farm types, farmer characteristics, farm location, partial productivities of labor and raw materials, and gross standard production defined in three classes). Estimation results displayed in Table 5.8 show that belonging to any farm type other than the farm type 1500 of COP farms increases the probability of reaching the superior level of the eco-scheme with an average marginal effect of approximately 6.6% for arable crop farms, 13.8% for mixed farms, and between 25 and 34% for livestock farms. The legal status of the farm (individual farm = 1) has no impact on this probability; the age of the farmer has a negative impact but with a very small average marginal effect close to 0%; and his/her education level (superior level = 1) has a positive impact with a marginal effect of 3.2%. Regression estimates indicate that location in a disadvantaged area and size (measured by the number of hectares of UAA) positively affects the likelihood of reaching the superior level with average marginal effects of 5.3% and 0.1%, respectively. In contrast, this likelihood decreases when the partial productivities of labor and raw materials are higher. In the same way, the likelihood of reaching the superior level decreases with the economic size of the farm measured by gross standard production (GSP) with a marginal effect of -6.2% between the 'middle' and 'big' farms, and of -12.2% between the 'middle' and 'very big' farms. 'Middle' farms have GSP

between €25,000 and €99,999; ‘big’ farms have GSP between €100,000 and €249,999; and ‘very big’ farms have GSP greater than €250,000.

Table 5.8. Probit regression model results

	Coefficient	Standard error	Average marginal effect	Standard error
Constant	0.939***	0.196		
1500: COP (reference)	-	-	-	-
1600: Arable crops	0.202**	0.081	0.066**	0.026
4500: Dairy cattle	1.043***	0.087	0.254***	0.020
4600: Beef cattle	1.646***	0.170	0.310***	0.019
4700: Beef and dairy cattle	1.286***	0.167	0.283***	0.023
4813: Sheep and goats	1.708***	0.205	0.313***	0.020
4840: Other herbivores	4.584***	0.674	0.335***	0.017
5100: Hog	1.643***	0.173	0.310***	0.020
5200: Poultry	1.144***	0.137	0.267***	0.024
5300: Hog and poultry	1.789***	0.269	0.317***	0.021
6184: Mixed	0.456***	0.076	0.138***	0.022
Disadvantaged areas	0.277***	0.058	0.053***	0.011
UAA	0.002***	0.000	0.001***	0.000
Individual status	-0.071	0.058	-0.014	0.011
Higher education ¹	0.172**	0.073	0.032**	0.014
Farmer’s age	-0.005**	0.003	-0.001**	0.000
Labor partial productivity	-0.000**	0.000	-0.000**	0.000
Raw material partial productivity	-0.174***	0.055	-0.033***	0.011
GSP1 (reference) ²	-	-	-	-
GSP2	-0.397***	0.080	-0.062***	0.011
GSP3	-0.683***	0.109	-0.122***	0.018
Share of well predicted observations	85%			

Source: Author estimation. *, **, ***: statistically significant at the 10, 5, and 1% level of significance, respectively. 1: Dummy variable equal to 1 when the farmer has a “baccalauréat” + 2 year level or higher (college education). 2: GSP is divided into three classes: GSP1 are ‘middle’ farms with GSP ∈ [€25,000 - €99,999], GSP2 are ‘big’ farms with GSP ∈ [€100,000 - €249,999], GSP3 are ‘very big’ farms with GSP ∈ [€250 000 - ∞].

5.4.3. Is the €20 difference between the two payment levels sufficient to incentivize farmers to change their practices to reach the superior level?

The eco-scheme is designed with two payment levels in order to reward farmers involved in more ambitious environmentally friendly practices. Estimation results presented above show that almost all farms would access the standard level without changing their current practices and that 15.0% of them would have to change their practices to reach the superior level. We now analyze to what extent the €20 difference between the two payment levels is sufficient to encourage farmers at the standard level only to change their practices to reach the superior level.

To this end, we regressed agricultural income before tax on the dummy variable Y ($Y = 1$ when the farm is at the superior level and $Y = 0$ when it is at the standard level) and a set of control variables (farm characteristics, farmer characteristics) for the four farm types of COP, arable crops, dairy cattle, and mixed farms. Estimation results are displayed in Table 5.9 where the endogenous variable is measured per unit of family labor (first model) and in Table 5.10 where it is measured per hectare of UAA (second model). They show that COP farms that reach only the standard level would need an eco-scheme premium per hectare of around €90 (first model) or €96 (second model)³ to compensate for their income loss between the standard and superior level and therefore encourage them to move from one to the other. The premium difference is of the same order of magnitude for dairy cattle (around €100 with the first model and €92 with the second model) but the estimated parameter associated with the dummy variable Y is statistically significant at the 10% level of significance only. The estimated parameter associated with this dummy variable Y is not statistically significant for either arable crop farms or mixed farms.

³ For the second model, the per hectare eco-scheme premium between the standard and superior level required to compensate for the income loss per ha is equal to the estimated coefficient of the dummy variable Y . For the first model, the required premium is calculated by using the estimated coefficient of the dummy variable Y multiplied by the ratio of the mean of units of family labor to the mean of UAA.

Table 5.9. Estimation results of the equation of agricultural income before tax per unit of farm family labor

Variables	Coefficients (standard errors)			
	1500	1600	4500	6184
Constant	5,826.77 (12,951.81)	66,316.00* (29,371.58)	15,679.38* (7,548.86)	12,344.32 (10,747.00)
Disadvantaged area (dummy)	-6,652.40** (2,997.26)	-1,168.99 (13,286.36)	-1,449.94*** (2,507.41)	-5,963.97* (3,050.03)
UAA (ha)	178.21*** (19.16)	201.62*** (57.93)	89.46* (25.21)	67.99*** (19.88)
Subsidies per UAA (€)	83.16*** (23.73)	-23.82 (23.55)	19.24 (10.73)	21.31 (14.39)
Individual status (dummy)	-6,111.33* (3,181.44)	-2,040.45 (10,105.04)	-2,929.83 (2,373.67)	956.61 (3,253.68)
Higher education (dummy) ¹	3,590.77 (3,835.10)	13,126.85 (11,078.16)	-2,660.90 (2,469.48)	6,991.07* (3,707.26)
Farmer's age (years)	-20.94 (135.68)	-678.51 (420.84)	0.36 (97.44)	-172.49 (135.28)
Family labor (unit)	-15,421.93*** (2,926.79)	-18,807.89*** (7,142.57)	-3,259.52* (1,671.48)	-3,174.22 (2,175.75)
Employed labor (unit)	7.41 (29.23)	49.21*** (16.05)	-1.09 (13.24)	50.72*** (10.59)
Crop protection expenditure (€ per ha)	-23.92 (27.63)	129.91*** (43.10)	8.02 (35.27)	69.94*** (22.15)
Fertilizer expenditure (€ per ha)	35.56 (22.84)	-74.38* (44.38)	2.78 (20.02)	1.42 (22.90)
Livestock units (LU)	-1.02* (0.600)	-1.24 (1.21)	0.34* (0.19)	0.36* (0.15)
Superior level of the eco-scheme (dummy)	-12,108.02*** (3,084.79)	1,471.30 (9,471.137)	-5,208.94* (3,295.48)	-5,086.48 (3,360.86)
R ²	0.13	0.10	0.06	0.13

Source: Authors' calculation. *, **, ***: Statistically significant at the 10, 5, and 1% level of significance, respectively. 1: See endnote of Table 5.8.

Table 5.10. Estimation results of the equation of agricultural income before tax per unit of hectare

Variables	Coefficients (standard errors)			
	1500	1600	4500	6184
Constant	26.20 (89.71)	909.70** (367.34)	223.64* (114.68)	87.08 (146.31)
Disadvantaged area (dummy)	-55.49*** (20.76)	418.18** (166.17)	-18.43 (38.09)	-68.86* (41.52)
UAA (ha)	-0.01 (0.13)	-4.94*** (0.72)	-2.20*** (0.38)	-1.28*** (0.27)
Subsidies per UAA (€)	0.64*** (0.16)	-0.26 (0.29)	0.30* (0.16)	0.52*** (0.20)
Individual status (dummy)	10.57 (22.04)	-264.13* (126.38)	-56.88 (36.06)	-9.81 (44.29)
Higher education (dummy) ¹	47.44* (26.56)	145.42 (138.55)	-25.55 (37.52)	54.91 (50.47)
Farmer's age (years)	-0.20 (0.94)	-11.64* (5.26)	0.86 (1.48)	-2.16 (1.84)
Family labor (unit)	57.95*** (20.27)	314.35*** (89.33)	175.16*** (25.39)	165.03*** (29.62)
Employed labor (unit)	1.43*** (0.20)	0.73*** (0.20)	0.25 (0.20)	0.72*** (0.14)
Crop protection expenditure (€ per ha)	-0.32* (0.19)	3.03*** (0.54)	0.35 (0.54)	1.05*** (0.30)
Fertilizer expenditure (€ per ha)	0.14 (0.16)	-0.75 (0.56)	-0.12 (0.30)	-0.17 (0.31)
Livestock unit (unit)	-0.01 (0.00)	-0.03* (0.02)	0.01** (0.00)	0.00 (0.00)
Superior level of the eco-scheme (dummy)	-95.76*** (21.37)	119.11 (118.45)	-91.90* (50.06)	-34.91 (45.75)
R ²	0.12	0.24	0.13	0.17

Source: Authors' calculation. *, **, ***: Statistically significant at the 10, 5, and 1% level of significance, respectively. 1: See endnote of Table 5.8.

5.5. Discussion

The eco-scheme is the main innovative measure of the new CAP. Targeting climate and environment issues with a much larger budget than Pillar 2 AECMs, the eco-scheme is expected to be the main instrument to align the CAP with the strategies of the European Green Deal focused on the agricultural sector; that is, the Farm to Fork Strategy (European Commission, 2020a) and the European Biodiversity Strategy for 2030 (European Commission, 2020b). The eco-scheme budget must be equal to at least 25% of the Pillar 1 budgetary envelope in each MS. In France, this percentage represents €1,684M per year out of a Pillar 1 annual budget of €6,736M (MASA, 2022a). Farmers who would not have access to the eco-scheme are thus implicitly taxed. They are theoretically encouraged to change their farming practices provided that the cost of change is lower than eco-scheme aid.

Our results show that the French eco-scheme would not encourage farmers to change their current farming practices. Almost all farms would reach the standard level of the eco-scheme by using one of the three access paths without changing their current practices. Furthermore, many farms would reach the superior level with unchanged practices. This applies more to cattle farms (91.4% for dairy cattle, 98.9% for sheep and goats, and 99.1% for beef cattle) than to COP (69.5%) and arable crop (79.6%) farms.

This means, for example, that the French eco-scheme would not induce cattle farmers to change their breeding practices and, in particular, to reduce their net greenhouse gas emissions (by decreasing their gross emissions and/or by increasing carbon storage) despite the reduction of greenhouse gas emissions being the central objective of the European Green Deal. It is worth remembering that agriculture ranks second in France in terms of gross greenhouse gas emissions with approximately 21% of the country total, and that approximately 70% of agricultural gross emissions come from livestock, mainly in the form of methane emissions by ruminants. At the same time, grasslands absorb annually approximately 13% of French gross agricultural greenhouse gas emissions (Ministry in charge of agriculture, 2018). Yet numerous studies have shown that there is significant room for improvement at low cost in that domain with, however, large heterogeneities among cattle holdings (Samson *et al.*, 2012; Veysset *et al.*, 2015; Dakpo *et al.*, 2017).

In the same way, few conventional farms would choose the environmental certification path to reach the superior level, although this is the only path that includes requirements in terms of pesticide and fertilizer uses in line with the quantitative reduction targets of the European Green

Deal (-50% for pesticide use and -20% for fertilizer use by 2030). Most farms would use one of the other two access paths and thus would not have to bother with explicit requirements in terms of fertilizer and pesticide use through the eco-scheme. The diversification access path requires that farms grow more categories of crops. In a context where there is no binding target in terms of reducing pesticide and fertilizer uses, the crop diversification requirement appears as a necessary condition for this reduction. However, this is not a sufficient condition since the reduction also depends on crop rotation from one year to the next with greater environmental benefits than crop diversification (Guyomard *et al.*, 2023). Since most farms already comply with the crop diversification requirement, at least at the standard level, very little improvement is expected for the remaining ones.

The extra subsidy of €20 per hectare at the superior level appears to be too low to encourage those COP farmers who would reach the standard level with unchanged farming practices to change their practices to reach the superior level. Econometric results do not support any conclusion on the ability of the extra subsidy to encourage (or not) farmers to move from the standard to the superior level for the farm types 1600 (arable crops), 4500 (dairy cattle) and 6184 (mixed farms). This is because the estimated coefficient associated with the dummy variable capturing belonging to the superior level is not statistically significant (or only at the 10% level of significance for dairy farms). This question of the ‘optimal’ level of the extra subsidy between the standard and superior level to encourage farmers to change their practices to reach the superior level requires further research. On this point, it would be interesting to compare the eco-scheme requirements with those of the ‘system AECMs’ for field arable crop systems and for herbaceous and pastoralist systems. Field crop system AECMs are characterized by very low adoption (Védrine and Larmet, 2021) despite higher payments per hectare than those of the eco-scheme at the superior level. However, in return, their environmental requirements are higher than those of the eco-scheme. The eco-scheme payment levels are also lower than the tax levels required to significantly reduce pesticide use (Féménia and Letort, 2016). Furthermore, grain prices are today higher than prices in the decade 2010-2020, which implies that a higher tax is required to trigger the reduction in pesticide use simulated by Féménia and Letort (2016). More generally, the higher the agricultural income, the lower the incentives to change farm practices as a result of eco-scheme payments. If agricultural product prices remain high, farms might not only give up eco-scheme payments but, even worse, increase the use of chemical inputs in simplified agricultural systems in order

to maximize their market profits. Of course, such a prediction also depends on input price evolutions.

This design of the French eco-scheme will certainly succeed in making it accessible to most farmers. The French Government explicitly stated this objective of access to the greatest number in its national strategic plan (MASA, 2022a). However, this comes at the cost of making it less effective in reducing the climate and environment footprint of French agriculture. The new delivery model of the 2023-2027 CAP gives each MS the responsibility for designing the CAP tools targeting global public goods like climate and biodiversity, while its farms will still have to compete within the European single market. This game structure naturally leads to a race to the bottom regarding climate and environmental issues since no MS will organize competitive distortions against its national farms (Dupraz and Guyomard, 2019). Furthermore, the realization and result indicators of national strategic plans do not reflect climate and environment impacts but rather expenditures and areas covered by the different CAP instruments and associated farming practices. Future bonuses and penalties that could affect the CAP budget of each MS depend on these indicators and not on an improvement or a deterioration of climate and environment impacts. Rooting the eco-scheme in largely spread practices is a way for each country to secure its national envelope of the CAP budget.

Eco-scheme payments do not come without public and private transaction costs. Based on a comparison of draft eco-schemes for 15 MSs, Runge *et al.* (2022) concluded that this policy innovation would not simplify the CAP although that was an explicitly stated objective of the policy (European Commission, 2017). Even if these 15 draft eco-schemes are very diverse, transaction costs are expected to increase everywhere for both the administration and the farmers. Furthermore, several studies have shown that transaction costs at the farm level associated with AECMs are mostly fixed costs, which contribute to excluding small farms (Ducos *et al.*, 2009; Espinosa-Goded *et al.*, 2013).

A review of the 2023-2027 CAP and of the different national strategic plans can be expected very soon. This will happen especially if the uptake of the eco-scheme measures is low and if the eco-schemes of other MSs are as environmentally unfriendly as the French eco-scheme. The work in progress in Brussels on the definition and/or the revision of directives and regulations in line with the objectives of the agricultural component of the European Green Deal increases the relevance of such a review. Further, penalizing pollution and rewarding environmental benefits appears necessary. This requires reducing the governance flaws mentioned above, as

well as strengthening the EU trade policy for agricultural and food commodities to avoid pollution leakages from the EU to non-EU countries through trade (Matthews, 2022).

5.6. Appendix. Methodological details

Table 5A.1. Agro-ecological access path: criterion of crop diversity on arable land areas

Crop categories of the eco-scheme	Criteria used to calculate eco-scheme points	Assumptions adopted for analysis
Temporary grassland and fallow land	Area \geq 5% of arable land (AL): 2 points Area \geq 30% of AL: 3 points Area \geq 50% of AL: 4 points	Information available in the FADN database
Grain and forage legumes	Area \geq 5% of AL: 2 points Area \geq 10% of AL: 3 points	Information on forage legumes is not available in the FADN database except for alfalfa
Winter cereals Spring cereals Root crops Spring oilseeds Winter oilseeds	Area in winter cereals \geq 10% of AL: 1 point Area in spring cereals \geq 10% of AL: 1 point Area in root crops \geq 10% of AL: 1 point Area in winter oilseeds \geq 7% of AL: 1 point Area in spring oilseeds \geq 5% of AL: 1 point Points in this category can be cumulated up to a maximum of 4 points If no point is obtained using the above grid but if the sum of the five areas \geq 10% of AL: 1 point	Barley is the only cereal for which we can differentiate the winter crop from the spring crop in the FADN database. For the other cereals and for oilseeds, we assigned the crop to the predominant type (winter or spring) at the national scale since one of the two types is very often much more prevalent: for example, less than 1% of wheat is spring wheat; wheat was thus considered as a winter crop.
Other crops and crops with potential for diversification	Area \geq 5% of AL: 1 point Area \geq 10% of AL: 2 points Area \geq 25% of AL: 3 points Area \geq 50% of AL: 4 points Area \geq 75% of AL: 5 points	Information available in the FADN database. Non-perennial fruits have not been considered
Permanent grasslands	Area \geq 10% of UAA: 1 point Area \geq 40% of UAA: 2 points Area \geq 75% of UAA: 3 points	Information available in the FADN database
Total area of arable land	Area $<$ 10 ha of AL: 2 points	Information available in the FADN database

Source: Own elaboration from the French NSP (MASA, 2022a).

Agro-ecological access path: Criterion of non-tillage of permanent grasslands

The criterion of non-tillage of permanent grasslands is calculated at the farm scale by dividing the number of non-ploughed permanent grasslands in year $n - 1$ by the number of permanent grasslands in year n . To show that this criterion is not likely to be binding, we take the example of a farmer who declared an area Z_{n-1} of permanent grasslands in year $n - 1$ and declares an area Z_n of permanent grasslands in year n . The farmer must declare the area Z_n in the spring of year n (April-May). This area Z_n is composed of three types of areas (assuming that the farmer does not acquire or sell new permanent grasslands), that is:

- (i) The area Z_{n-1}^1 of permanent grasslands in year $n - 1$ that was not ploughed between year $n - 1$ (01 September $n - 1$) and year n (31 August n);⁴
- (ii) The area Z_{n-1}^2 of permanent grasslands in year $n - 1$ that was ploughed between year $n - 1$ and year n , and re-sown in meadows;
- (iii) The area Y_{n-1} of temporary grasslands in year $n - 1$ that became permanent grasslands in year n by exceeding a duration of 5 years.

The area Z_n does not include the area Z_{n-1}^3 in permanent grasslands in year $n - 1$ that is transformed into annual or perennial crop areas in year $n - 1$ (permanent grasslands declared in year $n - 1$, ploughed between 1 September $n - 1$ and 31 August n , and declared as annual or perennial crops in year n : corresponding ha must be recorded under either the diversity criterion for annual crops or the inter-row coverage for perennial crops).

Suppose that the ratio of non-ploughed permanent grasslands to all permanent grasslands was equal to 100% in year $n - 1$, which implies that the corresponding farmer accessed the superior level of the eco-scheme on permanent grasslands in year $n - 1$. He/she will still access the superior level on permanent grasslands in year n if the ratio $Z_{n-1}^2 / (Z_n = Z_{n-1}^1 + Z_{n-1}^2 + Y_{n-1} = Z_{n-1} - Z_{n-1}^3 + Y_{n-1})$ is lower than 10%; he/she will access the standard level on permanent grasslands if this ratio lies between 10 and 20%; and he/she will no longer access the eco-scheme for permanent grasslands if the ratio is greater than 20%.

The way the ratio is calculated implies that the criterion related to permanent grasslands will very likely not be binding for farmers. This is directly linked to the fact that the numerator of the ratio (Z_{n-1}^2) is calculated using areas of year $n - 1$ while the denominator (Z_n) is calculated using areas of year n . The transformation of temporary grasslands into permanent grasslands (Y_{n-1}) increases the room for maneuver of the farmer while the transformation of permanent grasslands into arable/perennial crops (Z_{n-1}^3) reduces it. It is only when large areas of permanent grasslands are transformed into arable/perennial crops that the ratio Z_{n-1}^2 / Z_n may significantly increase and be superior to the thresholds of 10 and 20%. However, this will only

⁴ Generally, plowing takes place in autumn before the declaration of year n . If this occurs after the farmer declares his/her area in permanent grasslands for year n , he/she will have the possibility of providing a corrective declaration.

occur one year – the year of transformation – and not the following years (other things being equal). Furthermore, conditionality criteria require maintaining the total area in permanent grasslands at the regional level.

In the simulations, we therefore assumed that the permanent grassland criterion of the access path of agro-ecological practices was not binding.

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Chapter 6. General conclusion

The general objective of the PhD thesis is to explore whether environmental standards can be a tool for encouraging farmers to adopt environmental practices. To address this general objective, we conducted four studies focusing on environmental standards with requirements related to agricultural practices. We investigate environmental standards with varying definitions and scopes to cover a range of situations. In Chapter 3, we examine two private initiatives standards, whereas in the other chapters, we studied two environmental standards officially recognized by government authorities, the organic standard and the HEV standard. The requirements of the standards under study vary; the organic standard is stringent and generally requires a redesign of the production system, whereas the other standards are less stringent and incremental in nature. The stringency of requirements and consumer awareness of standards affect market differentiation and the level of the price premium. Among the standards studied in this PhD thesis, the organic standard is the most differentiated in the market and the one with the highest price premium. Conversely, the HEV standard offers limited differentiation and is still relatively unknown to consumers. Nevertheless, the government relies on this standard to achieve public objectives. In addition to the diversity of standards studied, we utilized a variety of databases to address our research questions. Chapter 3 relies on precise agronomic data at the plot level. Accounting data are employed for Chapter 2 at the territorial level and for Chapter 5 at the national level. Finally, Chapter 4 utilizes survey data.

In the first part of the conclusion, we present the key findings of the PhD thesis. Then, we discuss the implications of these results and their limitations.

The results of the studies conducted in this PhD thesis highlight that the adoption of environmental standards affects the performance of agricultural farms. In Chapter 2, we show that the adoption of organic agriculture certification negatively affects farm efficiency to an extent of 11.55% between 2014 and 2020 compared to conventional farms. This is explained by the fact that organic farms operate under a lower technology than conventional farms. Given the diversity of the environmental standards that farmers can adopt, Chapter 3 evaluates the influence of adopting a more stringent environmental standard at the field level. We demonstrate that the adoption of a more stringent standard that prohibits the use of the most toxic pesticides has a negative effect on the technical performance of the affected fields. It reduces wheat yield by approximately 2.5% compared to the less stringent standard and

decreases wheat quality. The test weight decreases by 0.54 kg/hl, and the protein content declines by 0.02 points.

As the adoption of environmental standards negatively impacts farm performance, various channels are needed to encourage their voluntary uptake. The results from Chapter 4 highlight that farmers are highly responsive to market-based economic incentives. Winegrowers are more inclined to adopt a contract when a 30% premium complements the base price. They are also sensitive to options for compensation in the case of yield loss. Winegrowers prefer contracts that include yield compensation through a cooperative fund or contain a guaranteed income per hectare clause. In contrast, the conclusions drawn from Chapter 3 indicate that farmers opt for the most stringent environmental standard, even when monetary incentives are minimal, approximately €1.19/ton. Unfortunately, the available dataset does not provide a comprehensive understanding of the underlying motivations. We can hypothesize that adopting the most stringent standard on certain plots may allow them to access a different market and diversify their sales outlets. We can also consider noneconomic motivations, including social factors, farmers' environmental awareness, and their access to information on practices. Indeed, adopting the more stringent standard on some plots entails regular technical visits by a cooperative technician.

In Chapter 4, we delve deeper into the role that cooperatives, as key actors in the supply chain, can play in encouraging the adoption of organic farming practices by offering specific attributes within their contracts. The results reveal heterogeneous preferences among winegrowers, allowing us to identify three distinct winegrower profiles: the *Organic lovers*, the *Reluctant to organic*, and the *Reluctant to change*. The *Reluctant to organic* group exhibits a positive attitude toward the possibility of adopting a new contract on only 50% of their land. In contrast, the *Reluctant to change* winegrowers view this option negatively. They also have a negative perception of the possibility of receiving advice from the cooperative on economic and labor organizations in addition to technical advice. Only the *Organic lovers* winegrowers, who represent 13% of the sample, hold a positive view of attributes related to the organic farming and conservation agriculture standards. Our findings underscore the importance of cooperatives offering tailored contracts. Furthermore, they suggest that while voluntary contracts provided by cooperatives can serve as a potential tool to increase the adoption of organic farming, complementary measures will be needed to expand the adoption of organic farming to a larger share of winegrowers.

Public policies have also embraced environmental standards to promote the adoption of environmentally friendly practices and thus achieve policy objectives. In Chapter 5, we focused on the most recent policy that relies in part on environmental standards, the eco-schemes. Our findings indicate that the French eco-scheme is unlikely to incentivize farmers to change their existing agricultural practices. Almost all French farms will access at least the standard level of the eco-scheme, and 85% of them will reach the superior level. The complementarity among the three paths simplifies access to the eco-scheme. The environmental certification path is the least stringent at the standard level, allowing the majority of farmers to access the eco-scheme. However, at the superior level, it is the most demanding path, with only 32% of farmers meeting the HEV specifications and thus accessing the higher level of the eco-scheme through this path. At the superior level, the agricultural practices path is the least demanding. The environmental certification path also enables farmers to attain the specific level of organic farming. Furthermore, we show that the additional subsidy of €20 per hectare at the superior level appears to be insufficient to encourage farms specialized in dairy cattle and in cereals, oilseeds, and protein crops to alter their practices. Since eco-scheme subsidies do not incentivize the evolution of farmers' practices toward more environmental practices, the French government may raise the eco-scheme thresholds during the review of the 2023-2027 CAP programming to justify the environmental nature of these subsidies to the European Commission.

To reach a higher adoption rate, environmental standards can complement agri-environmental policies such as AECM, which also rely on the voluntary adoption of practices by farmers. Our studies show that intermediate standards (i.e., less demanding than organic standards) increase the adoption rate of environmental practices by farmers. In Chapter 3, wheat production following the requirements of the most stringent standard, which prohibits the use of the most toxic pesticides, accounts for 10% of the annual French wheat production. For comparison, only 1% of French farms have contracted an AECM with requirements based on pesticide reduction (Vedrine and Larmet, 2021). In Chapter 4, all members of the studied cooperative adopted two environmental standards, Agriconfiance and HEV, which can also be characterized as intermediate. This cooperative aims to go further and encourage all its members to adopt the organic farming standard. Nevertheless, for this more stringent standard, our study highlights that few winegrowers are willing to change their practices to comply with organic farming requirements. These results underscore the existence of a trade-off between the adoption rate of standards and their levels of stringency. Higher stringency levels ensure superior

environmental benefits but with a limited number of participants due to the challenging requirements. Conversely, lower stringency levels increase participation but may compromise the quality of environmental benefits. We observe the same trade-off in agri-environmental policies based on voluntary adoption. Chabé-Ferret and Subervie (2013) highlight that AECM with the highest adoption rates are the least demanding. In Chapter 5, the ineffectiveness of the eco-scheme policy arises from the selection of easily achievable thresholds for a significant number of farmers. This policy could have been an incentive given that eco-scheme subsidies account for 25% of the direct payments received by farmers. However, the existence of a trade-off between the level of environmental stringency and adoption rates raises the question of determining the optimal stringency level for environmental standards. Among theoretical works, Bonroy and Constantatos (2015) highlight that the requirements of standards set by private actors are generally not defined at the optimal level; they are either too stringent or not stringent enough. They identify five potential explanations for this phenomenon: demand effect, strategic effect, reservation quality effect, profit margin effect, and supply restriction effect.

Regarding spatial continuity in the adoption of environmental practices, our results show that supply chains can play a role under certain conditions. In this PhD thesis, we focused on the role of cooperatives, as they are major stakeholders in the supply chain. In Chapter 3, we do not observe spatial continuity in the adoption of environmental standards and therefore environmental practices. The standards studied are adopted at the field level, which does not encourage spatial continuity in the adoption of practices at the farm level. Moreover, there are multiple cooperatives in the studied territory, limiting the possibility of spatial continuity at the territorial level. In Chapter 4, the context is different because the cooperative under study is the only actor collecting grapes in the PDO territory. There is an opportunity for territorial continuity in the adoption of environmental practices if the cooperative engages all its members. This is the case for the Agriconfiance and HEV standards. Thus, the coexistence of environmental standards and GI seems promising. However, our results show that it will be challenging in the short term to ensure spatial continuity in the adoption of organic farming because many members of the cooperative are reluctant. To ensure spatial continuity in the adoption of environmental practices, adding environmental practices to the PDO requirements would be an interesting avenue to explore. To date, few PDOs have already done so (Belletti *et al.*, 2015; Marescotti *et al.*, 2020). However, the trend could reverse starting in 2024 if the proposal for regulation on EU geographical indication, which was approved by the European

Parliament on May 31, 2023¹, is, after an agreement in trilogue, voted during the plenary session of October 2023. Indeed, the regulation states that “producers of geographical indications should be encouraged to adhere to sustainability standards that are more stringent than the mandatory ones, encompassing environmental, social and economic objectives. Such specific requirements should be set out in the product specification or in a separate initiative”.

The studies conducted in this PhD thesis have some limitations. It is important to exercise caution when attempting to generalize the findings from this PhD thesis. The results from Chapters 2, 3, and 4 must be considered within the specific characteristics of the agricultural productions under scrutiny and the context of the regions being studied. Despite the lack of generalization, we opt for case studies as they offer methodological advantages and provide access to additional data beyond the one available in national databases. In Chapter 2, the focus on a particular region and farm specialization enable a comparison of farms operating within a more uniform environment and production technologies compared to the national FADN database. In the case of Chapter 3, the database that was utilized offers highly detailed technical data concerning input utilization and specific technical outcomes, such as wheat yield and quality. Such granular information is typically absent from national databases. Having access to this detailed data allowed us to go beyond the scope of most studies that focus on the effect of input use only on yield, by measuring its impact on product quality as well. Finally, in the case of Chapter 4, our case study focuses on a sample of winegrowers from a single cooperative. While this limits the external validity of our findings, it allowed us to tailor contracts that were most relevant to the winegrowers, so the study's internal validity increased. A second limitation of the PhD thesis relates to the scarcity of variables describing farmers' practices and environmental indicators in the databases. In Chapter 2, a more comprehensive analysis could have been conducted if we had access to data on bad output. We could have assessed the impact of the adoption of organic farming, not only on the technical efficiency of farms but also on their environmental efficiency. In Chapter 3, access to data concerning pesticide toxicity would have enriched our analysis and allowed for a more concrete evaluation of the environmental advantages arising from the adoption of the more stringent standard. In Chapter 5, we had to resort to additional databases and make assumptions to compute the eco-scheme indicators. The

¹ Amendments adopted by the European Parliament on 1 June 2023 on the proposal for a regulation of the European Parliament and of the Council on European Union geographical indications for wine, spirit drinks and agricultural products, and quality schemes for agricultural products, amending Regulations (EU) No 1308/2013, (EU) 2017/1001 and (EU) 2019/787 and repealing Regulation (EU) No 1151/2012 (COM(2022)0134 – C9-0130/2022–2022/0089(COD)) https://www.europarl.europa.eu/doceo/document/TA-9-2023-0210_EN.pdf

European Commission's proposal to transition from the current FADN to the FSDN (Farm Sustainability Data Network), which would collect additional data on environmental and social practices alongside existing data, is expected to mitigate such limitations in future research (European Commission, 2022). Another shortcoming of this PhD dissertation is that we could not consider the timing of standard adoption. This aspect would have been relevant in Chapter 2, as one might expect a learning effect over time and thus an effect on farm efficiency (Sipilainen and Oude Lansink, 2005). In Chapter 4, it could have been interesting to explore if farmers take into account in their decision the possible learning effect. To do so, we could have included in the contract attributes the possibility of higher monetary support and higher advisory assistance during the first years following the adoption of organic practices.

In this PhD thesis, we studied standards based on sets of requirements regarding the implementation of environmental practices. The underlying assumption is that the adoption of these practices has positive effects on the environment. However, several studies have shown that the adoption of environmental practices by farmers does not always lead to the expected environmental outcomes. To address this issue, AECMs in which payment is contingent on results rather than the adoption of practices have been developed. To date, their development and adoption remain limited. In France, in the European Hamster habitats preservation AECM, a bonus payment is used to reward the achievement of environmental results (Osswald, 2019). Additionally, there is a trend toward the development of labels informing consumers the environmental impact of products rather than the environmental practices according to which they are produced (Deconinck *et al.*, 2023). The carbon footprint label is the most common type of impact reporting label. Impact reporting labels based on life-cycle assessments are also emerging and encompass a broader range of environmental impacts (Deconinck *et al.*, 2023). The challenge when considering multiple environmental impacts is determining the weight assigned to each type of indicators. To tackle this challenge and to promote a harmonized framework, the European Union developed the Product Environmental Footprint methodology, which details a weighting for 16 environmental indicators in (Damiani *et al.*, 2022). The French initiative of the Eco-score² is based on this methodology and incorporates five additional criteria (labels, transport distance, environmental performance of the country of origin, packaging sustainability, and endangered species). The final score is communicated to consumers with a letter grading system from A to E, which is similar to the French Nutri-Score.

² <https://docs.score-environnemental.com/>

After an experimentation phase, in 2024, the French government plans to deploy the Eco-score on food products. It will be voluntary at first. The advantage of labels based on life-cycle assessments is that they hold the entire supply chain responsible for sustainability, not just farmers for the practices they implement. The development of these impact reporting labels is relatively recent. In the future, it would be interesting to investigate whether these labels will act as substitutes or complement to existing standards based on the adoption of environmental practices. Additionally, in the case of impact reporting labels, the need to determine an optimal level of environmental requirements no longer arises, unlike with environmental standards. Impact reporting labels could offer more continuous incentives to farmers for practice improvement and provide greater flexibility in selecting a cost-effective combination of practices to enhance the environment (Deconinck *et al.*, 2023).

Although environmental standards can act as instruments for promoting the adoption of environmental practices among farmers and increase the adoption rate, products with environmental standards remain niche markets. Despite various surveys and findings in the economic literature indicating that consumers are generally willing to pay extra for products with environmental standards, we observe that their market shares remain low. The disparity between consumer declarations and actions is partly explained by hypothetical bias and social desirability bias (Lusk, 2018). Scaling up could arise with impact reporting labels. In France, it could be driven by making mandatory the display of the Eco-score on food products. In such a scenario, it would be interesting to investigate the impact of the display of the Eco-score on farmers' practices and assess whether products with higher Eco-scores benefit a price premium. The Eco-score may not benefit farmers; it may act as a deterrent for products with lower scores, encouraging stakeholders to change their practices, similar to the effect of the Nutri-Score, which prompted food manufacturers to adjust their recipes (Hélias *et al.*, 2022).

While this PhD thesis shows the potential of environmental standards as valuable tools, they should not be viewed as a standalone solution to mitigate the negative environmental impacts of the agricultural sector. Ibanez and Grolleau (2008) argue that environmental standards alone cannot fully internalize pollution up to the optimal level. Additionally, the voluntary contribution of consumers to environmental preservation through environmental standards has limitations since consumers can only contribute through the purchase of food items, which inherently have quantity restrictions (Kotchen, 2005). A mix of different initiatives from supply chain stakeholders and policies is needed. In this PhD thesis, we focus on environmental

standards and a public policy, eco-schemes, both based on the voluntary adoption of environmental practices. Another way to change farmers' practices is to make the adoption of environmental practices mandatory through regulation as thus define them as minimum environmental quality standards to achieve.

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Titre : Effets des standards environnementaux sur les exploitations agricoles

Mots clés : standards environnementaux, politiques agro-environnementales, filières, contractualisation, certifications, performances

Résumé : Cette thèse de doctorat étudie si les standards environnementaux (SE) peuvent inciter les agriculteurs à adopter des pratiques environnementales. J'explore les effets de l'adoption de SE sur les performances agronomiques et économiques des exploitations. L'adoption volontaire de pratiques environnementales pouvant être influencée par des facteurs autres qu'économiques, j'examine les attributs des contrats agricoles favorisant l'adoption de SE. De plus, comme les politiques publiques ont eu recours ces dernières années aux standards pour atteindre leurs objectifs, j'analyse l'effet de l'intégration de SE dans les politiques publiques sur les pratiques des agriculteurs. Nous montrons que les exploitations en agriculture biologique opèrent sous une frontière de production inférieure aux exploitations conventionnelles mais qu'elles sont efficaces vis-à-vis de leur propre frontière

de production. Aussi, l'adoption d'un SE interdisant l'utilisation des pesticides les plus toxiques a un effet négatif sur les performances techniques des parcelles de blé concernées. La prime de prix associée au SE le plus contraignant compense tout juste l'effet négatif de l'adoption du SE sur la qualité du blé. Cette thèse illustre que les initiatives des filières et la mise en place de politiques publiques sont complémentaires pour encourager l'adoption de pratiques environnementales par les agriculteurs. Les agriculteurs réagissent fortement aux incitations économiques et aux options de compensation en cas de perte de rendement. Toutefois, l'efficacité de ces deux approches dépend d'un compromis entre le niveau d'exigence environnementale et le taux de participation.

Title : Impacts of environmental standards on farms

Keywords : environmental standards, agri-environmental policies, supply chain, contracting, certification, performance

Abstract : This PhD thesis aims to investigate whether environmental standards may incentivize farmers' adoption of environmental practices. First, it explores the effects of adopting environmental standards on the agronomic and economic performances of farms. Second, as voluntary adoption of environmental practices can be influenced by factors beyond purely economic interests, I examine the attributes of farming contracts that can encourage the adoption of environmental standards. Last, as in recent years, public policies have increasingly included standards to achieve their objectives, I analyze the impact of integrating environmental standards into public policies on farmers' practices. We show that organic farms operate under a lower production frontier than conventional

farms but they are efficient regarding their own production frontier. Besides, the adoption of a standard prohibiting the use of the most toxic pesticides has a negative effect on the technical performance of affected wheat plots. The price premium of the more stringent environmental standard merely compensates for the negative effect of the standard's adoption on quality. This thesis illustrates that supply chain and public policy initiatives can be complementary to incentivize the adoption of environmental practices by farmers. Farmers are highly responsive to market-based economic incentives and to options for compensation in the case of yield loss. However, the effectiveness of both approaches relies on a trade-off between the level of environmental requirements and the participation rate.