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ABSTRACT

The objective of this article is to explore how value chains adapt quality standards governance to account for societal issues such as sustainable development. It aims to better understand how public and private standards co-exist or hybridize within sectors by focusing on two kinds of quality: 'intrinsic' product quality and environmental quality. It offers a new analytical grid combining the literature on innovation economics with that on value chain governance. A case study on the French durum wheat sector for couscous and pasta production is offered to test this grid. To this end, we conducted interviews with the main representatives of the French chain. The results show that there is international competition on product standards and that environmental standards are struggling to emerge in France. These results are discussed in terms of public/private design, homogenization/differentiation processes, vertical/horizontal relationships and links between social values and economic interests. We emphasize that broadening the range of quality attributes impacts the ways in which a value chain organizes itself.

1. Introduction

There is a growing social demand to account for the environmental impacts of economic activities. But embedding environmental values into economic processes requires broadening the conception of product quality to include new sets of criteria. Following this line, the integration of environmental criteria enables the emergence of new standards in markets, which can expand the scope of outlets. In general, standardization refers to processes by which product characteristics are defined and specified along the chain. Standardization produces standards, which, following Busch (2000), we define as the institutionalized quality of a product (*i.e.* a controllable or measurable product attribute) or a production process (*i.e.* a normalized procedure that does not necessarily translate into a measurable information – *e.g.* the use of child labor). Economic actors are thus confronted with the challenge of jointly managing the quality associated with the product and these production conditions which refer to more complex societal expectations to take into account (de Olde and Valentinov, 2019). The literature on quality has highlighted the importance of stakeholder coordination in defining and ensuring quality (Busch, 2000). Because it shapes and selects the quality of products, standardization is a key challenge for product innovation and differentiation (Ponte and Gibbon, 2005). This issue is especially relevant in the agri-food sector in the context of significant growth of private standards, which challenge the organization of supply chains (Henson and Humphrey, 2010; Bain et al., 2013) and the governance of standards (Nelson and Tallontire, 2014). As noted by Boström et al. (2015), standards are part of the governance challenge facing globalized supply chains that need to become more sustainable and responsible.

The objective of this article is to explore how value chains can adapt quality standards governance to account for societal issues that are complex to address. It offers a new analytical grid combining the literature on innovation economics with that on value chain governance in order to analyze the relationships between the governance modes of standards and the eco-innovation capacity of the industry. It argues that the creation and governance of standards are the results of interactions between actors that consider regulatory systems, end-market demands, and production and processing technologies. It addresses the governance issues raised by the coexistence of different standards (public versus private, product versus production conditions) within the same value chain. For the latter, the article compares two types of standards, that of "intrinsic" product quality (*i.e.* the minimum desired values of a given set of attributes that raw materials or end-products must have in terms of buyers' expectations) and that of environmental quality (*i.e.* the sets of relevant environmental impacts all along the product's life cycle).

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To test our grid, we focused on the French durum wheat sector. The durum wheat industry provides an illustrative case study for addressing standardization-governance issues. First, it is a small market (compared to field crops like soft wheat or corn) with a small number of international actors and important quality issues. Durum wheat is indeed consumed almost exclusively as pasta or couscous and is an important component of Mediterranean diets. Durum wheat, which is genetically different from soft wheat, has a different chain of production from collection to processing than soft wheat, which is used for both feed and food (Abécassis et al., 2021). On the production side, when collecting is organized, farmers choose between soft and hard wheat based on the price difference between the two, bearing in mind that durum wheat is a demanding crop that is slightly less productive than soft wheat. The bulk of durum wheat traded on world markets therefore feeds the Mediterranean region (notably Italy and North African countries) (Ranieri, 2015). Guaranteeing the quality of pasta and couscous then requires that durum wheat meets certain "intrinsic" quality standards (protein levels, vitreousness levels, etc.). Moreover, despite European and French agricultural regulations that promote more environmentally friendly farming practices, environmental standards are struggling to be implemented in this sector (Blasi et al., 2015). It is therefore important to better understand how national standards are set and updated in order to encourage more sustainable agrifood chains. While many studies have analyzed how environmental standards have emerged and spread in emblematic sector such as palm oil (Oosterveer, 2015) to our knowledge there is little research on the grain industry, characterized by lower "value to volume ratio" than other crops; thus, this study on durum wheat is intended to fill this gap. As a producer, processor, exporter, and consumer of durum wheat, France offers a relevant case study to investigate coordination in standards (Abécassis et al., 2021). The configuration of the durum wheat sector is different from that of Italy, which is the reference country in the world for this crop: the industrial structure of the French durum wheat sector is more concentrated and the pedoclimatic conditions are less favorable than in Italy, which results in the weak development of organic practices in France. In this sense, analyzing the configuration of the French durum wheat sector can serve as a reference point for other countries wishing to develop this industry even to start producing durum wheat in the context of global warming. Pasta and couscous, as low-processed, low-cost and widely consumed products, can actually contribute to the vegetalization of the diets, supported by the Farm to Fork strategy of the European Green Deal.[1] The combination of durum wheat cultivation with pulses is particularly emphasized for this purpose (Lascalfiari et al., 2019).

The paper is structured as follows. Section 2 examines the literature on innovation, focusing on the links between eco-innovation and quality standards, and on the baselines for analyzing the diversity of standards and inter-firm coordination within a sector, in order to propose an analytical grid for the governance of standards. After detailing the methodology for data collection and interviews (Section 3), results are presented on how the durum wheat actors manage information on products quality, both for technological and environmental standardization (Section 4). They reveal that international competition on 'intrinsic' standards has led the actors in the French sector to converge on a national standard; and that the primacy of this standard hindered the emergence and institutionalization of environmental standards for durum wheat. These results are discussed in order to examine under which conditions different standards may co-exist or hybridize within sectors that could foster environmental innovations (Section 5).

2. Standardization and eco-innovation: mutual embeddedness

The recent economic literature on the link between standardization and innovation is relatively scarce (Blind et al., 2017). However, standardization is a factor that triggers increasing returns to adoption, whether on the supply side through economies of scale or on the demand side through network externalities (David and Greenstein, 1990). We therefore offer a new analytical grid for the creation and governance of standards drawing on both the literature in eco-innovation and in value chain governance.

2.1. Standardization and innovation as socio-technical configurations

At the firm level, eco-innovation is driven by the regulation-market demand-technology tryptic (Rennings, 2000). Firms produce and benefit from both knowledge and environmental externalities. These joint externalities reinforce the importance of regulation as an incentive/constraint for innovation. Following this line, Porter's hypothesis states that environmental regulations can induce efficiency that help improve competitiveness, which has a positive effect on innovation (Porter and van der Linde, 1995). This body of work also emphasizes the complementarity of technical and organizational innovations in creating and disseminating innovation within and across sectors (Milgrom and Roberts, 1995). When the benefit of innovation is not directly appropriable by the firm that innovates, this complementarity is even more crucial in order to involve all the actors in the chain. This is often the case for environmental benefit that can occur during use by end consumer as well as during the production or processing stage.

Eco-innovation processes also refer to the industry in which firms operate (Malerba, 2002). The evolutionary approach to socio-technical systems views an industry – or a value chain, as the result of an accumulation of innovations that help to stabilize it or to lock it in a particular configuration (Geels, 2004; Rundgren, 2016). Within a value chain or sector, product innovations coevolve with process innovations, routines, and practices, and standards and their modes of governance can thus be considered as contributing to the stabilization of a sector. Geels (2004) suggests this system evolves according to its capacity: (i) to integrate radical innovations developed in niches, such as environmental innovations responding to society's new expectations; (ii) to consider the main orientations for the future, such as the expectation of a transition towards sustainable systems.

Finally, the configuration of the industry affects the relationship between innovation and product quality specifications. Vertical and horizontal relationships between actors in an industry set different configurations for standardization processes. It may be in the interest of firms to agree on a common private standard and to continue to compete on the market. However, they can also compete over their own standards (Besen and Farrell, 1994). In configurations where dominant actors have the ability to impose and then use standards to their benefit, it creates barriers to innovation (Henson, 2008). In configurations where there are high market uncertainties, private standards appear to be more efficient in promoting innovation. Conversely, public regulation effectively stimulates innovation when markets are more stable. Innovative capacity within a sector thus depends on the level of market uncertainty and on the nature of the standard (public regulation or private standards) (Blind et al., 2017).

2.2. The multiplication and intertwining of standards

Over time, standards have multiplied and piled up because of the evolution of regulations and markets, and the internal characteristics of sectors. Furthermore, the rise of private standards is also associated with a growing overlap with public ones (Bain et al., 2013). On the one hand, public standards can refer to mandatory norms (regulation) or to voluntary commitments (organic farming, for example). On the other hand, private standards can be either legally mandated (such as ISO certification) or voluntarily accepted. In addition, voluntary private standards grew at different scales, from individual firms to national or international collective scales (Henson and Humphrey, 2010). Indeed, society is pushing supply chain actors, in particular those in the agri-food

[1] See https://ec.europa.eu/food/horizontal-topics/farm-fork-strategy_en.

Table 1
Typology of quality standards.

	Food Safety	Product Quality	Social and Environmental Standards
Examples	Limits on pesticide use and residues Control food additives Hygiene requirements	Product composition standards Product cleanliness specifications Grading schemes Nutritional claims	Organic farming standards Environmental and biodiversity protection 'Fair trade' standards
Main characteristic	Set by public regulation	Mainly managed by firms	Involving a broad range of public and private actors

Source: adapted from World Bank, 2005.

Table 2
Framework for analyzing types of inter-firm coordination.

Managing quality Producing quality	Codified information available	Codified information not available
Suppliers are not able to meet processors' expectations	**Captive value chains** "Producers and collectors are able to give the information on the product specifications but their capacity to give the required specification is low so processors need to intervene to obtain the quality they want"	**Hierarchy** "Product specifications (on environmental aspect for example) are not codified and competent collectors are not available. Processors need to develop design and production skills in-house"
Suppliers are able to meet processors' expectations	**Modular value chains** "Producers and collectors can deliver the specified quality and have the capacity to respond to the needs of the processors, so processors don't need to closely control design and production processes"	**Relational value chains** "Producers and processors develop complex interactions which often creates mutual dependence and high level of asset specificity. Confidence is required that may be managed through reputation or proximities (geographical or social)"

The mode of organization of the sector depends on existence or not of information codified regarding product quality, and on the ability of the supplier to meet processor's expectation on quality (or on the capacity of processors to enforce the quality criteria in transactions). (adapted from Gereffi et al., 2005).

industry, to innovate and include an ever-increasing number of quality criteria in response to broad societal issues (Jaffee et al., 2011).

This trend (multiplication and intertwining) raises questions about how the information should be managed along the chain. Gereffi and Lee (2009) identified three types of standards targeting product attributes and involving quality management issues (see Table 1): food safety, mainly integrated into supply chain actors' decisions through government regulations; product quality (technical and technological), mainly managed by firms and sometimes through quality certifications (regulatory or not); and social and environmental quality specifications, requiring greater control of production and processing processes by society.

As a result, the change in standards has been accompanied by a broadening of the relationship between companies and their environment, from classical relations between firms to consumer relations and even with civil society (Jaffee et al., 2011). The addition of quality criteria as well as the greater number of actors involved in their definition and governance reinforces the strategic dimension of the standardization processes at work in value chains, in particular regarding eco-innovation capacity. The extension to environmental and social criteria raises questions for actors all along the value chains, not only for the definition of standards but also for their use, as they are subject to debate (de Olde and Valentinov, 2019). Excluding food safety standards, which mainly result from public regulation,[2] we will focus on "intrinsic" product quality and external environmental criteria. The processes of standardization of intrinsic and environmental qualities reveal the interplay of private and public actors when setting and using standards. Yet, the links between the organization modes of the actors in the sector and the governance modes of the standards remain to be analyzed.

2.3. Governance of standards and coordination in sustainable value chains

Generally, the literature on quality standards tends to contrast situations in which products are highly homogenized from those in which products are differentiated. But the growing product segmentation and the development of private standards show that it is no longer the case (Nelson and Tallontire, 2014; Rundgren, 2016). The industry's awareness of sustainability issues requires reconceptualizing the supply chain by integrating social and environmental values (Pagell and Wu, 2009; Govindan et al., 2016). Indeed, when they integrate sustainability requirements, companies extend the governance of the value chain and standards to other stakeholders, such as NGOs, public actors and/or third-party certification. Yet standardization that seeks to homogenize product characteristics and standardization aiming at differentiation are interrelated and co-evolve, which makes it fundamental to examine all

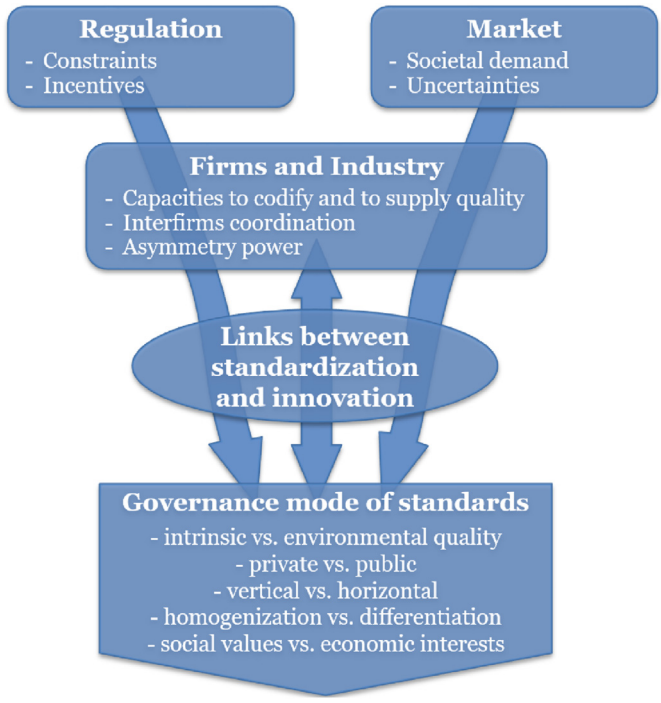

Fig. 1. Analytical grid for the governance mode of standards in terms of intrinsic vs. environmental quality management, private vs. public standard, vertical vs. horizontal relationships, strategies of homogenization vs. differentiation of products, and social values vs. economic interests. Governance mode of standards depends on the configuration of the sector (how quality is codified and supplied; how firms coordinate themselves, and the power structure), and on regulation and market-demand, which also influence the configuration of the sector.

[2] Food safety standards are imposed on industry actors by public regulation and are therefore not negotiated during transactions. However, the fixation of thresholds values for food safety criteria also result from a process of standardization.

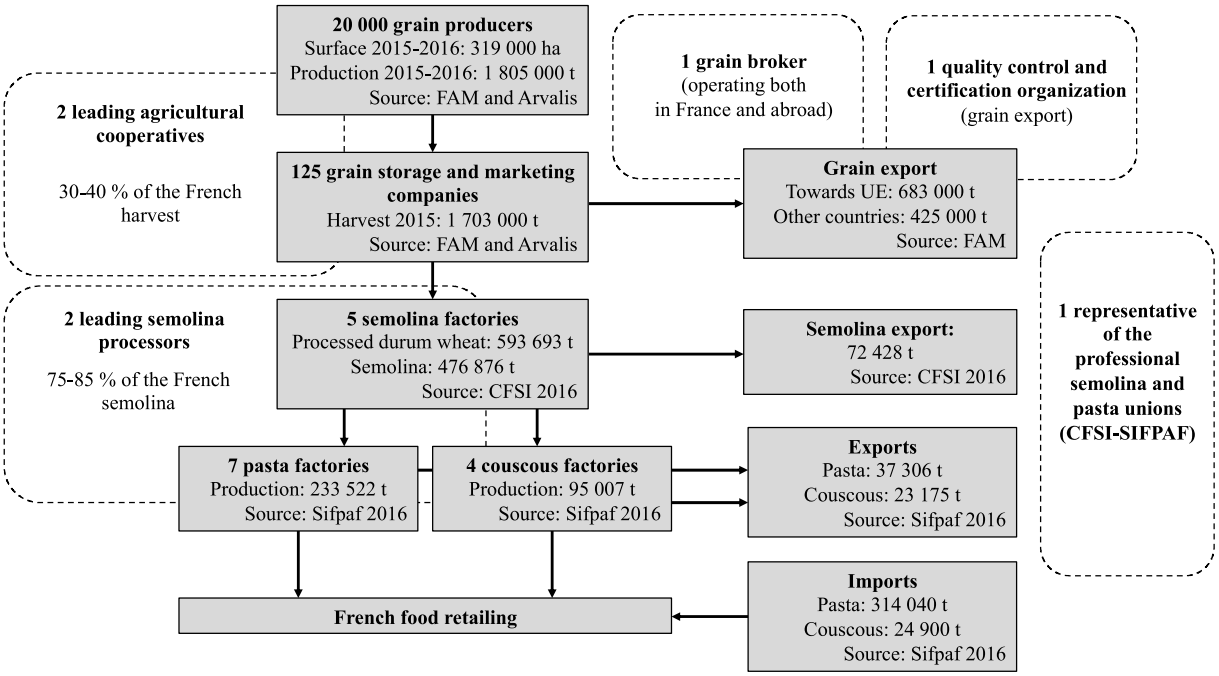

Fig. 2. Structure of the French durum wheat sector (shaded boxes), from grain production to French and exports food retailing (pasta and couscous), and organizations surveyed (white dotted line boxes), representing 30–40% of grains and 75–85% of the semolina produced in France. The two leading processors surveyed hold 4 semolina factories, 3 pasta factories and two couscous factories.

these situations.

In both cases, product standardization, in particular when product attributes are specified in contracts. seeks to reduce transaction uncertainties and may lead to different forms of coordination (Busch, 2000; Ponte and Gibbon, 2005). Gereffi and Lee (2009) found that in sectors with a high concentration of suppliers and buyers, both actors have the market power, resources, and leverage to strongly determine the definition and management of quality standards. Yet, while the literature has mostly focused on the power struggle between manufacturers and retailers, very little attention has been paid to modes of coordination driven by grower-processor relationships in agrifood chains (Luhmann and Theuvsen, 2017). To this end, we use Gereffi et al. (2005) framework, which identifies four inter-firm governance types related to the capacities of actors to manage and produce quality: first, whether it is possible to codify the information on product attributes, which means standardizing production; and second, whether suppliers are capable of producing the quality required (see Table 2). In other words, this framework makes it possible to question the compatibility between standards and modes of inter-firm governance, particularly when standards require more complex coordination, as is the case for environmental standards.

From the literature on eco-innovation and on global value chain governance, we built a general analytical grid. It hypothesizes that standards governance is conditioned by internal industry factors, including technology, resources and mode of coordination, and external factors, including regulation and market pressure (see Fig. 1). This grid was designed to better understand collective and individual standardization strategies by questioning them along five interrelated dimensions: (i) the nature of standards (private vs. public), (ii) the type of inter-firm or interorganizational relationships (horizontal vs. vertical), (iii) the standardization strategy (homogenization vs. differentiation), (iv) the links between social values and economic interests and (v) the type of standard (intrinsic vs environmental quality).

In the French durum wheat sector, despite society's demand for more environmentally friendly practices, actors have difficulties to eco-innovate. The way in which intrinsic and environmental standards are managed by the actors in the sector is determined, to a certain extent, by the way in which the sector is organized (and vice versa), which may be a barrier to introducing new standards or innovations. We can therefore use our grid to explore the interconnectedness between the dominant intrinsic standard and emerging environmental standards.

3. Methods

To explore and unpack how actors are confronted to existing institution, we chose to adopt the case study method, based on interview data and secondary sources (websites, press articles, regulatory texts, etc.). By institution we mean the "*cognitive, normative, and regulative structures and activities that provide stability and meaning to social behaviors*" (Scott 1995, p.33). Interviews provide information on the actor's strategies in regards to standards. Secondary data provides information on the rules by which standards are institutionalized. Interviews and secondary data enable an analysis by triangulating the data (Yin, 2012).

The case study focuses on the French durum wheat sector (Fig. 2). In France, the sector is characterized by a highly concentrated downstream industry, with three semolina producers (first processing) who also manufacture pasta and couscous (second processing). Upstream, production has increased along with the power of agricultural cooperatives, which collect durum wheat from their member farmers and now hold key positions in the durum wheat trade. However, cooperatives have not developed activities in processing, so there is no integration between upstream and downstream, which could undermine environmental innovations (Fares et al., 2012). Since the early 1990s, production has fluctuated between 1.5 and 2.5 million tons per years, depending on public policies and climate conditions. France is a top player in the market, both domestically and for exports, which is now the main outlet. An open public-private platform has been created in 2013, dedicated to improve the sustainability of durum wheat production and transformation.[3]

The issues that motivate the quality requirements of the different actors can vary, depending on their position in the sector. So we

[3] See https://www6.inrae.fr/umt-novadur/content/download/3328/34306/version/1/file/Plateforme+Bl%C3%A9+Dur.pdf.

interviewed a diversity of actors from the French sector, with a focus on agricultural cooperatives and semolina processors. We surveyed two leading agricultural cooperatives that work as Storage Organizations (SOs) in different collecting areas. Two of the three existing semolina processors that are also producers of pasta and couscous and with complementary product lines were also interviewed. An interview was also conducted with a quality control and certification organization that holds a leading position in the Mediterranean port used to export French durum wheat. A broker, operating both in France and abroad, was surveyed as well. Their role being to put in relation the buyers with the sellers also they have a good knowledge of the information related to the quality. The final interview was conducted with the representative of the professional semolina and pasta unions who has an overall vision of the issues related to the quality of durum wheat in France.

The interview guides were constructed according to the category of actors, in order to adapt the themes to the positioning of each actor (Table S1 in supplementary materials). The first part of the guide concerns basic information on the organization surveyed (scope of activities, history, etc.). Three main themes were then addressed in the light of our theoretical questioning: (*i*) durum wheat quality management; (*ii*) durum wheat exchange modalities; and (*iii*) the emergence of environmental sustainability criteria. These themes were discussed with all the actors, adapting the questioning according to the type of actor in order to take into account their specificities. Additional documents were also provided by interviewees before, during or/and after the interviews.

The seven semi-structured interviews were conducted in 2015–2016 and lasted 66 min on average. A summary of the interviews was sent to the interviewees for validation and mention of the data to be kept confidential. Additional questions were also asked if needed. We then conducted a double content analysis by actor and by theme. The synthesis by actor allowed us to have a global vision of the perception and strategies of each actor on quality management. The synthesis by theme made it possible to structure the following results. Excerpts from these interviews are given to illustrate the results (in italic in section 4).

4. Standards along the durum wheat value chain

While the criteria used in trade to define the quality of the products are mainly technological ('intrinsic'), environmental quality standards are struggling to develop. In this section, we report the results on the capacities of producers and processors of durum wheat to codify (4.1) and to produce (4.2) the expected technological and environmental qualities.

4.1. The capacity to codify information: the hidden complexity of standardization

4.1.1. Product quality

Product quality criteria must ensure that the durum wheat produced will have the desired properties for the quality of end products. In this industry, standards have mainly been defined to facilitate processing into semolina and then into pasta or couscous. The desired technological standards for quality were then mainly established by processors: criteria (test weight, presence of blackpoint, protein content, vitreousness levels, etc.) and corresponding minimum values are therefore standardized to guarantee the efficiency of the production process as they influence the amount of semolina obtained for a given unit of durum wheat. In addition, market arguments are also used to impose standards, as proteins and vitreousness influence the gluten network that is critical for pasta texture, and in particular the cooking resistance. So, standards are designed to shape and/or ensure that end products meet the needs of the final consumers (e.g. the possibility to overcook pasta). In addition, French processors have become involved in the public-private selection system, so that varietal selection provides farmers with varieties that meet their criteria. Each year, the CFSI and SIFPAF unions publish a list of recommended varieties.[4] Then the national standards are also the result of coordination between private actors and public authorities. The public organizations rely on these standards to report on the quality of durum wheat during their annual evaluation.[5]

Public authorities have long used standardization criteria to ensure quality levels at the sale of raw materials. In France, the public reference is the EU Regulation EC687-2008[6] that defines values for each criterion that durum wheat must meet to be considered "sound, fair and marketable." This regulation was part of European intervention schemes, which are no longer in force today, but is still used as a 'minimum' reference in the market. This "a minima" quality standard leaves room for stakeholders to set their own standards. The Canadian system, known as "grading", is an alternative approach to the quality standards that prevail internationally.[7] To qualify for Grade 1 (the most demanding), durum wheat must meet the required thresholds on all criteria.[8] A poor score on a single criterion is enough to downgrade the wheat, making the Canadian grading system stricter than the European one. Thus, with this system, the buyer has *ex ante* information on a minimum quality level for a set of criteria.

The protein content is a '*de facto*' standard both internationally and in France. At the international level, the protein levels demanded on the markets are generally high, at around 14%. According to the interview data, French actors are converging towards a '*de facto*' standard based on a protein content around 13.5%. This standard meets the common interests of processors to guarantee the quality of finished products, and of cooperatives for their export outlets.

> "The protein level is often the first criteria used. The main goal is to have batches with high protein levels" (SO).

In the end, the Canadian grading system provides highly codified information. The EU assessment of admissible quality depends more on the parties involved. In France, the product quality standard has historically been established in correspondence to varietal improvement, with the goal of developing and sustaining a French crop that meets the needs of French companies. However, the focus of French actors on a high level of protein appears to be an obstacle to developing the environmental quality of durum wheat.

4.1.2. Environmental quality

There is currently no set and institutionalized definition of the environmental quality of durum wheat (except for organic farming). In fact, very few sales transactions specify this type of criterion, which would require prior agreement on the criteria to be met and the incentives to be provided to meet them. In our case study, good environmental practices in agriculture involve reducing synthetic inputs (fertilizers, pesticides, etc.) to limit nitrogen loss and toxic molecules in air and water, as well as reducing energy consumption. Yet, nitrogen supply is correlated to the protein rate in grain. So, there may be trade-offs between technical (protein content) and environmental (nitrogen fertilization) criteria. As a result, we observed few production contracts requiring good environmental practices from farmers. On another hand, organic farming has a

[4] See https://www.cfsi-sifpaf.com/cfsi-documents.php.

[5] See https://www.arvalis-infos.fr/file/galleryelement/pj/59/64/43/32/enq_cer_qualitebd_a9037118523826290884.pdf.

[6] See https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32008R0687&from=en.

[7] The grading system in Canada is the result of a centralized public organization, the Canadian Wheat Board, which was dissolved in 2012 and privatized in 2015 (Brewin et al., 2017). Canada produces more 50–60% of the wheat durum traded each year in international markets. As a result, the Canadian standards have become a norm in international trade.

[8] See https://grainscanada.gc.ca/en/grain-quality/official-grain-grading-guide/04-wheat/primary-grade-determinants/cwad-en.html.

label guaranteed by third-party certification, and this market is currently booming in France. However, it is struggling to develop in the durum wheat sector, with less than 0.5% of certified organic areas in 2015 (Agence Bio, 2016).[9]

> "Other than supply chain or production contracts, there are no environmental sustainability criteria considered during sales. Actors are thinking about it, the big pasta manufacturers are talking about it, but nobody is implementing any actual practices" (SO)

> "To reduce the sector's environmental impact, first we have to measure and quantify [that impact]. I'm not sure we know how to do that properly, objectively." (processor).

> "Environmental sustainability is something we are working on. But in the contracts, you can't put everything in. Is there a definition of environmental sustainability? It's rather implicit in quality criteria today" (professional union).

In France, the quality standard has historically been set on durum wheat that could be easily processed and this therefore favored practices that increased the yield and nitrogen fertilization of durum wheat to the detriment of organic farming. So, in the absence of clear signals about society's and the markets' environmental demands, for the time being, processors and SOs essentially think about durum wheat in terms of intrinsic product quality. Overall, there is little economic incentive downstream of the sector to promote good environmental practices and little communication on this aspect to consumers.

4.2. The capacity to produce the quality required as strategic interactions in the value chain

The interviews revealed that both agricultural cooperatives and processors play a key role in establishing the quality of durum wheat. The former, because of their privileged relations with farmers, and of knowledge of outlet markets; the latter because of they concentrate power in the value chain. As a result, SOs and processors are at the heart of the challenges of (re)organizing quality management.

The ability of suppliers to provide the required quality to buyers obviously depends on the soil and climate conditions that affect the quality of durum wheat. But they also depend on the way in which the actors coordinate themselves and on the associated quality incentives (contracts). The interviews revealed that agricultural cooperatives play a key role in establishing the quality of durum wheat as they handle its classification and storage.

> "At the harvest, we have no idea about the quality, and as we get information [about that], we sort based on the criteria of quality standards that will enable us to better promote the crop" (SO).

> "We start with the 'sales' standard and then adjust depending on the quality available" (SO).

> "The durum wheat is stored in silos at the port according to criteria: this year, it's protein, last year, it was blackpoint; every year it changes. It depends on the quality of durum wheat and the most important criteria, which are protein, blackpoint, and the test weight" (Certifying Agency).

Over 20 years, cooperatives have faced major changes in their contractual relations along the chain in line with the development of durum wheat exports. Farmers increasingly want greater visibility on the sale of their durum wheat, either with fixed-prices negotiated pre-harvest or by maintaining control over post-harvest sales through on-farm storage or depositing in the cooperative's silo. These different contractual arrangements determine how a cooperative can obtain the intrinsic quality standards it requires. In pre-harvest contracts, the cooperative may set quality targets that are supported by a premium. Nevertheless, the scope of these incentives is conditioned by the market and competition with other crops, which may or may not be conducive to growing durum wheat. Moreover, the cooperatives recognize that their power to direct quality is shrinking.

> "It's not easy to encourage quality, for example protein levels, because the market is volatile and the price difference with soft wheat varies a lot. Durum wheat is viewed as a speculative crop, with farmers changing radically from one year to the next" (SO).

> "I can't encourage quality; it depends on downstream actors. It's a real consumer market with a real relationship between buyer and seller. The SO can't decide on its own. And the same is true for processors" (SO).

> "The determining factor is the demand and the price difference with soft wheat. When soft wheat is selling well, farmers are going to grow it because it's easier technically to grow and the yields are better" (Certifying Agency).

In addition, as over 20 years production of durum wheat has increased, cooperatives became less dependent on French industry and expanded their export outlets. Therefore, the two leading cooperatives, in order to be competitive in international markets, created in 2013 a joint venture company that sell and buy durum wheat, both in domestic and international markets. This progressively gave them good knowledge about how international markets function concerning quality assessment and about the related price-quality issues.

> "This kind of organization allows us to handle all destinations and origins. Having a global vision means we can anticipate things a little better. Statistical data aren't reliable. If we're not able to analyze what the world's major durum wheat operators are reporting and understand it, we're blind" (SO).

Faced with changes in supply, French processors had to adapt. Historically, processors, and in particular the industry leader, establish long-term contractual relationships with cooperatives to direct production in accordance with their needs. Processors favored agreements with the cooperatives located near their plants in order to optimize logistics costs and flexibility. Depending on the quantities and quality available each year through these agreements, the processors then made spot purchases, enabling them to constitute batches corresponding to their requirements. For this, they extended their search beyond nearby durum wheat basins, even abroad when necessary or to take advantage of market opportunities. However today, these multi-year contracts are declining and the majority of durum wheat purchased by processors is currently done with spot purchases.

> "Other than this historical supply chain contract with a nearby French processor, most of our production is traded on the open market" (SO).

> "France had a surplus production with demand unstable, so the SOs needed to contract with processors to ensure the sale of the harvest in France. Today, demand is greater than the supply and with volatility in the markets, the problem of needing to make sure to sell the harvest is less of an issue" (broker).

This trend to adopt external procurement strategies is strengthened as processors have no guarantees about the quality of wheat that has been grown according to specifications. On spot markets, they can obtain the desired technical qualities of durum wheat but this does not allow them to support more sustainable agricultural practices.

In France, adding environmental criteria mainly means reducing inputs, which would require diversifying rotations to include grain legumes and accepting lower yields. One processor strongly supports the

[9] The percentage of surface area certified organic in France in 2015 was 0.85% for soft wheat and 1.01% for barley.

development of organic farming by investing in relationships with producers in order to offer organic French pasta to consumers. But the uncertainties of production make it difficult for the actors to organize, which leads this processor to partly obtain supplies from Southern Europe, where the soil and climate conditions are more favorable for organic farming. However, the situation has been changing since 2018, as organic surface areas have risen sharply, and the processor has committed to 100% French supply for its organic brand.

> "The organic market in France is very complicated. There are two regions in France where this is growing, but there are quality problems because they're wanting yields. On the other hand, in Sicily or Spain, whether they grow organic or not, it's the same. It's not the same in France and the organic durum wheat equation is not simple. There's still work to do" (processor).

In conclusion, the organization of the French industry and the changes in trade between cooperatives and processors show a shift from captive governance (historically, French durum wheat was supplied to French processors) to modular governance, due to alignment with the global market for both durum wheat sales and purchases. This modularity, which aims to match supply and demand at a given time, does not encourage long-term investment and coordination between actors, to the detriment of taking better account of environmental criteria. For the time being, the development of organic farming for durum wheat is weaker than for other crops, which can be explained by the need to reach the protein levels required by the industry. This indicates that the existence of a standard is not a sufficient criterion to facilitate coordination between actors. In this niche market, the supply chain tends to be organized in a relational way.

5. Internal and external factors that hinder the development of environmental standards

The results show the difficulty the French sector faces to innovate environmentally and to develop environmental standards. The lack of a system for codifying environmental qualities may be seen either as a cause or as a consequence of the lack of environmental innovation and the low level of transactions in sustainable durum wheat. The French durum wheat industry illustrates how exogenous factors (regulation and market-demand) are useful, but not sufficient to upgrade supply chains (5.1). The configuration in which the industries function in managing existing standards (the coding of quality and information) is therefore fundamental to introduce environmental standards (5.2).

5.1. The role of the regulation and market-demand as drivers of innovation and standardization

The results show the superposition of standards: those related to the issue-area (highly institutionalized technical standards vs. still embryonic environmental standards) and those related to the market (international vs. domestic). This double overlay creates uncertainty in durum wheat trading markets and jeopardizes chain resilience. The way of managing quality, mostly based on mutual agreements during trade transactions, encourages a private governance of standards. Although it follows that regulation will not drive environmental innovation, this does not necessarily imply that standards themselves are privatized. Moreover, the existence of a public standard, such as organic agriculture, does not guarantee that the actors will succeed in coordinating themselves on this standard. In France, one of the semolina manufacturers has been trying to develop an organic durum wheat chain for a long time but it is only very recently that he has committed to 100% French supply for its organic brand.

Apart from regulation, the second external factor that can drive environmental innovation and standardization in upgrading supply chains would be creating demand for 'sustainable' or 'green' products. However, the demand for "green" products may remain low, particularly if consumers' perception of end-products is good enough. This may be for pasta because of its image as a staple consumer product with good nutritional and environmental benefits. This weak pressure from consumers and society does not encourage the actors of the sector to eco-innovate, as shown by Mylan et al. (2015) for bread supply chains in the UK. Conversely, the environmental indictment of palm oil production (Oosterveer, 2015) has been a driving force in coordinating actors to set up certification schemes and retailer-driven standards.

In sum, consumer and citizen demands, whether addressed through regulation or the market, will not necessarily be enough to guide an industry toward more sustainable practices. In addition, in such a configuration where narrowly-defined markets are subject to large price variations, it alters the building of long-term relationships between sector actors due to opportunistic and speculative behaviors. In such context, adopting environmental criteria, which requires increased coordination among actors, is hampered.

5.2. New types of coordination to develop environmental standards: co-existence or hybridization

Results suggest that the "intrinsic" quality assessment practices of actors have been effective in coding information, which resulted in information available on product quality. So, depending on the degree of the cooperatives' competence in supplying the qualities of durum wheat that the markets need, the organization of the sector oscillates between a captive one (concentrating power in the hands of processors who impose their quality standards) and a modular value chain (increasing the growers' skills to deliver the required quality), with a variety of combinations that co-exist. However, introducing environmental standards in sales transactions requires an organization that enables tacit information flows between actors. This may be achieved by large firms that have the capacity to manage the standard (hierarchical organization) or by means of a more diffuse organization favoring relationships between a varied set of actors (relational organization).

Each form of organization poses specific challenges to both standards governance and innovative capacity (see Table 3).

Captive mode: Captive organization refers to a dominant actor/branch of the downstream value chain capable of making the standard effective. The standard, whether public or private, is a means to develop strong vertical, even horizontal, relationships. For the dominant actor/branch, the goal is to be able to guarantee the quality of products and processes and to control traceability (Garcia-Torres et al., 2019). Depending on the scale (firm, national, international) at which the standard is implemented (Henson and Humphrey, 2010), it may be relatively dominant on the market, increasing the desirability for suppliers to subscribe in order to secure their outlets. A "captive" mode of governance is likely to favor a dominant standard for the benefit of the most influential actors in the value chain (Nelson and Tallontire, 2014). There is then a risk that the standard will evolve more in line with the interests of these stakeholders, which could lead to a mismatch with the stated objectives of the standard. This appears to be the case for both public and private standards. Allen and Kovach (2000) show how the criteria of the organic standard in the USA in the 1990s evolved significantly under the influence of the market rather than the consideration of environmental effects.

Modular mode: When suppliers' skills increase, private actors can cooperate in order to increase the extent of attributes and levels of quality for the standard. But this modularity can result in a multiplication of private standards, which can lead firms to intensify the competition on standards (Nelson and Tallontire, 2014). This multiplication of standards also makes it possible to develop product differentiation for both suppliers and buyers. These standards can be implemented either at the firm, national or international level.

Hierarchical mode: When codified quality information is not available, the issue becomes an agreement on the criteria and quality

Table 3
Governance challenges in environmental quality management.

Mode of governance Criteria	Captive	Modular	Hierarchy	Relational
Availability of codified information	High	High	Low	Low
Suppliers ability to meet clients' qualitative expectations	Low	High	Low	High
Private vs. public standards	The reinforcement of codification requires the implementation of private standards or the private management of a public standard.	The reinforcement of the codification is carried out in a privileged way by a private standard. Modularity can refer to the multiplication of private standards.	The standard can be public or private but it is privately managed by a leading firm.	The standard may be public or private, but it is likely to be managed privately given the uncertainty about the quality available.
Vertical vs. horizontal relations	Strong vertical (and horizontal) relationships driven by the dominant actor/component of the supply chain.	The multiplication of standards can result in increased competition between firms on standards.	A dominant actor leads the standardization process and develops (quasi-)integration.	Horizontal multi-stakeholder relationships are multiplying to enable the standard to be developed.
Homogenization vs. differentiation strategies	- processors have an interest in homogenizing intermediate products - producers have an interest in playing on the dominant standard	The multiplication of standards makes it possible to develop product differentiation both for processors and for producers.	For the dominant actor, the environmental standard can be part of a differentiation logic.	The development of the standard requires the homogenization of production.
Social values and economic interests	Values are aligned on or disqualified by the interests of the dominant actor/component	Actors have the capacity to embed social values in specific standards	The importance given to values depends on the strategy of the dominant actor	The development of the standard requires an consensus on the social values that make up the standard
Levels	Firm, national or international	Firm, national or international	Firm	Regional or national
Examples	French *de facto* standard	Specific markets	Barilla's strategy	French firm's strategy

Sources: Authors. Each mode of organization of the sector implies different way of governing standards. The introduction of environmental standards challenges this governance depending on the public/private nature of standards, verticalization or horizontalization of relationships, homogenization vs. differentiation of products strategies and the level of standards' implementation.

thresholds to be adopted. A hierarchical approach can be observed when the market is asymmetrical, with a concentration of downstream actors, giving them great responsibility in driving these kinds of changes. This is the case in Italy where the "pasta" industry leader has invested in integrating environmental objectives (Blasi et al., 2015). In this form of organization, processors must ensure that compliance with environmental conditions is compatible with the technological criteria required for making end products. The dominant actor in the chain (*i.e.* the one who integrates every link in the production chain) is most likely to privately manage the standard, with the goal of homogenizing the end products.

Relational mode: Relational organization appears to be a promising way to share values between a set of heterogeneous actors when information cannot be easily codified and therefore transmitted. This would involve multiplying the interdependencies between suppliers and processors, notably by different networks, including those outside the strictly professional sphere, to enable a standard to be developed. But, as the relevant criteria relate to broad societal issues, there are more actors to include in their definition (*e.g.* consumers or citizens) than simply the industry's direct stakeholders (Pagell and Wu, 2009). Garcia-Torres et al. (2019) points out that environmental traceability requires blurring boundaries and integrating non-traditional supply chain actors such as NGOs into the same ecosystem. This orients choices towards collective private management of the standard based on multi-partner organizations. Relational standards governance remains dependent on its capacity to be aligned with the strategies of local actors (Loconto et al., 2015). Finally, the challenge of building the standard is associated with a logic of homogenization of production in order to trigger increasing rates of adoption.

In conclusion, environmental standards are stacked up on technological standards. The case of durum wheat shows the complexity of combining standards. Indeed, promoting locally produced durum wheat with sustainable practices does not guarantee the technological quality required by industry. This may explain why manufacturers are cautiously committing themselves to guaranteeing the French origin of the durum wheat in their products, even though consumers increasingly favor local/national products. The link between quality and origin is also subject to debate for industries in Italy, where the government has made it mandatory since 2018 to mention the origin of durum wheat on pasta sold in Italy[10]. Thus standardization processes can be complex and Ruben and Zuniga (2011) suggest that public standards provide market incorporation (on local institutions' and producer's behaviors), while private labels improve product quality (at the scale of production and management practices). In the agri-food industry, the ability to combine different standards and forms of organization is a great challenge in meeting the diversity of expectations about agriculture and food (Luhmann and Theuvsen, 2017). Thus, innovation is not only based on technology but also on the ability of agrifood firms and chains to manage a variety of standards and organizational forms. Co-existence and hybridization of standards and modes of coordination are, therefore, an important element of innovation, both at the individual firm level and at the collective level of the industry. This broadens the perspective from a competitive approach between standards (Ruben and Zuniga, 2011) to one where firms or sectors can try to organize a diversity of standards among themselves but also by integrating other stakeholders from outside the industry.

6. Conclusion

The present article has focused on the conditions favoring the development of environmental standards in agro-industrial sectors. Based on a case study, it brings to light how the interplay between the market, regulation, and industry organization affect the emergence of environmental standards, and therefore hinder or foster environmental innovation. The studied supply chains are organized by technological standards that are most often private ones. Yet environmental issues require that, in some way, interests in the value chain be aligned with broader social values. Standards are institutional instruments designed to encompass this compromise. There are indeed multiple standardization issues in the durum wheat sector that raise questions about the actors' strategies. Technical standards resulted from historical processes of convergence between various actors of the sector, which enabled increasing returns to adoption and concentration within the industry.

[10] See https://news.italianfood.net/2018/02/14/pasta-labels-must-show-wheats-origin/.

Internationally, there is competition between a regulatory standard that distinguishes quality levels (Canadian) and a 'private' standard resulting from a trade-off between the actors (French). In France, the '*de facto*' standard is based on coordination between collectors and processors, which has evolved from a captive organization to a modular organization as collectors have improved their position on the international market. Employing environmental standards would require new forms of coordination in order to define the criteria of these standards and to strengthen stakeholders' ability to comply with them. In France, environmental specifications have yet to be defined within the sector, so relational or hierarchical coordination methods seem to be better suited to managing environmental quality. Relational coordination appears to be efficient to ensure that standards involving a growing set of quality attributes, and in particular a wider set of actors, are effectively and legitimately enforced.

Developing environmental standards requires questioning the compatibility between technical and environmental standards, both in terms of the criteria adopted and the methods of coordination among actors. It is important to broaden the approach to standards by integrating issues related to their public versus private dimensions, homogenization versus differentiation processes, vertical versus horizontal relationships and links between social values and economic interests. Indeed, an environmental standard may be based on technical criteria different from prevailing criteria. The analytical grid offered here enables us to situate the impacts and challenges of the creation and use of standards in relation to stakeholders' organizational forms. This grid can be useful for industry actors in thinking about the strategic options for organizing their relationships in relation to their standardization goals. This is particularly the case with the need to mention the origin of the agricultural products they use, supported by European regulation and by consumer demand, and which pushes companies to develop partnerships with the agricultural sector at the national level for better traceability. The co-existence of different modes of coordination is an avenue to be explored for the most influential organizations in agrifood chains. It can also be used by a broad range of stakeholders to better understand the issues and impacts of standardization processes in value chains.

Ultimately, each of the factors that may drive standardization relates to the way in which the merits of innovations are evaluated by society. Typically, a demand for a given good or service arises in a market when that good or service enables individuals to meet their needs. Whether through regulation or the market, the incentive to innovate and standardize ultimately refers to society's assessment of product quality, which tests the legitimacy of innovation, products, and the industry to meet social norms.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

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