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PDO Economy and Quality Agri-Food District in the wine sector: Blockchain and digitalization as tools for the twin transition

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Abstract

The twin transition has great potential for the development of the wine sector, although its benefits for the valorisation of the Protected Designation of Origin (PDO) economy and at the quality districts level are not explored in depth either in the theoretical or empirical literature. The study aims to contribute to this knowledge gap from a strictly conceptual perspective, by investigating benefits and obstacles that Blockchain and digital technologies can have to favour the creation and implementation of a quality wine district towards a sustainable path. Based on the literature background and a case study approach, the Vermentino di Gallura PDO Quality District, this study discusses the prospects and hypotheses of introducing Blockchain technologies and other digital tools at district level and the challenges and opportunities for fostering its sustainable transition. Preliminary results suggest that this transition could benefit the local supply chain and its territory over different pillars of sustainability, although obstacles can be expected along the implementation path. Obstacles can be in various areas – among which are the breadth and variety of processes included within the boundaries of the digital transition and the inter-organizational nature of the twin transition.

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Introduction

The concept of twin transition has received strong input from the current EU policy's priorities aiming at 'twinning the green and digital transitions in the new geopolitical context' (European Commission, 2022). As such, the term twin transitions "not only refers to two concurrent transformational trends (the green and digital transitions) but also to uniting the two transitions" (*ibidem*, p. 7, 2022) and coupling digital technologies with sustainable development, to focus on their interconnection and a simultaneous process of change towards two related but distinct goals (Müller *et al*., 2024). Anyway, separate, well-established research traditions on both digitalization and sustainability formed a major part of the literature, and only recently, a growing interest in investigating them jointly has emerged (Müller *et al*., 2024). Indeed, the twin transition implies considering how green and digital may enter a virtuous cycle in which the green/digital sphere is at the starting point of the cycle – as a driver – and at the end of it – as an outcome – producing an intersection that is mutually beneficial and creates room for further improvement.

Moreover, it should be noted that joining the green and digital world requires connections both in the various technologies, in the transition paths, outcomes and feedback, and for a systems approach in which they reinforce each other (Montresor & Vezzani, 2023).

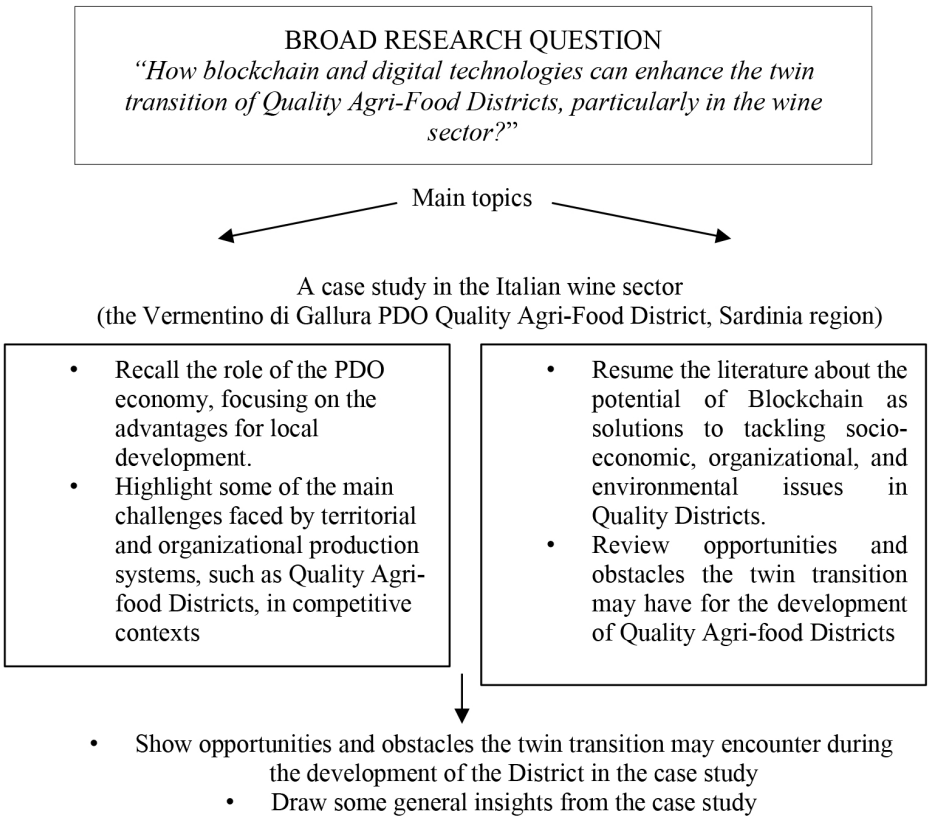
The growth of Information and Communication Technologies over the last decade has provided several opportunities to overcome some of the challenges faced in agriculture, although some side effects and digital divides have been signalled in the Italian case (Gnesi *et al*., 2022). Recent literature has devoted a lot of attention to applying Blockchain technology and other digital tools to the agri-food sector (Chiaraluce *et al*., 2024; Priya *et al*., 2024). The agri-food supply chain is considered among the most promising areas for the future development of digital technologies towards a sustainable transformation of the sector (Myshko *et al*., 2024; Rana *et al*., 2021).

The innovative contribution of the study compared to the existing literature is that in this case, it is not a question of applying Blockchain to a single company but to a (specific) Quality Agri-Food District. Furthermore, in the current literature, Blockchain technology has been analyzed as a tool capable of overcoming critical issues or facilitating production processes at the individual company level (Cuel & Cangelosi, 2020; Dicuonzo *et al*., 2021; Van Huy *et al*., 2024), at the consortium level (Agata *et al*., 2021; Zheng & Jiang, 2024), in the hospitality and tourism sector (Van Huy et al, 2024), for environmental sustainability (Myshko *et al*., 2024) and in the application of Social-Life Cycle Assessment (D'Eusanio & Petti, 2024) (just to mention a few). In this research instead, we focus on the use of Blockchain as a tool

capable of supporting the *districtisation* process (intended as a transition from a local production system to a Quality Agri-Food District) and at the same time, promote the digital and ecological transition.

Figure 1 summarizes the conceptual framework of the study.

Figure 1 - The conceptual framework of the study



The research uses the "case study" as a research method (Yin, 2009) which is applied in economics when "the structure of a given sector or the economy of a city or region is being investigated" (p. 4).

The paper is structured as follows: the first part of the work describes the PDO economy and the Quality Agri-Food District, and reports the literature background about Blockchain systems and digital tools for the wine supply chain; the second part describes the case study (the PDO

Vermentino di Gallura Quality Agri-Food District, Sardinia region); the third part discusses the role of Blockchain Technologies in supporting the District implementation, both along the wine supply chain and the non-winery actors, i.e. by enlarging its boundaries to the tourism valorization and the twin transition.

1. Background

1.1. *The Protected Designation of Origin economy and Quality Agri-Food District: advantages and criticalities*

The term "PDO Economy", which has now become part of the common language, has a very recent origin and was coined for the first time in the XVI Ismea-Qualivita Report on Italian agri-food and wine production PDO, Protected Geographical Indication (PGI) and Traditional Specialty Guaranteed (TSG) (Rosati, 2018). In 2021, it became part of the Treccani Vocabulary and was defined as a "Segment of the production and transformation of agricultural products intended for Geographical Indication food, which constitutes an important part of the national agri-food value".

The economic value of the Italian agri-food system reached 20.2 billion euros in production value by 2022, representing a 19% increase compared to 2020. In terms of export value, it amounted to 11.6 billion euros, marking a 22% growth since 2020. This growth contributed to a 20% increase in the overall turnover of the Italian agri-food sector (Ismea-Fondazione Qualivita, 2023). The system includes 853 PDO, PGI (Protected Geographical Indication), and TSG (Traditional Speciality Guaranteed) products. It supports approximately 890,000 jobs in the GI (Geographical Indication) supply chains, involves over 195,000 operators within GI agri-food and wine supply chains, and comprises 296 Protection Consortia authorized by the Ministry of Agriculture, Food Sovereignty, and Forestry (Masaf).

The wine sector is particularly significant, contributing to 62% of all PDO and PGI products registered in Italy. It accounts for 56% of the production value of bottled products within the total agri-food and wine market and 60% in terms of export value. The GI wine supply chain engages around 110,000 operators (including winemakers and bottlers), supports 340,000 employees, and consists of 128 Protection Consortia approved by Masaf.

While the PDO economy centered on the wine sector impacts the entire national territory, approximately 75% of the economic value of PDO/PGI wine is concentrated in five regions: Veneto, Piedmont, Tuscany, Friuli Venezia Giulia, and Trentino Alto Adige. Beyond the quantitative aspects,

the role of food as a driver for regional development is essential (Hall & Mitchell, 2004; Rachao *et al.*, 2018), particularly for products with designated origins and the associated territorial governance (Ciliberti *et al.*, 2024; Ismea-Fondazione Qualivita, 2023).

Most of the PDO economy is characterized by district-based production organizations. The legislation introduced in Italy in 2001 played a pivotal role in establishing quality agri-food districts. The Law for the Orientation and Modernization of the Agricultural Sector (Legislative Decree No. 228 of May 18, 2001) defined "districts" as governance tools that allow local communities autonomy to make decisions regarding suitable interventions on a limited territorial scale. Quality Agri-Food Districts are described as "local production systems, even interregional, characterized by significant economic presence and production interrelationships, with interdependence of farms and agri-food enterprises, and by one or more certified or protected products in compliance with applicable Community or national regulations, or by traditional or typical products" (Article 13).

In 2011, the National Institute of Statistics identified 141 industrial districts, predominantly situated in Northern and Central Italy. Notable examples include the Prosecco DOC district in Veneto, the San Daniele-Parma agri-food district in Emilia Romagna, the agri-food district of La Morra in Piedmont, the Pecorino district in Sardinia, and the fruit and vegetable district of Pachino in Sicily.

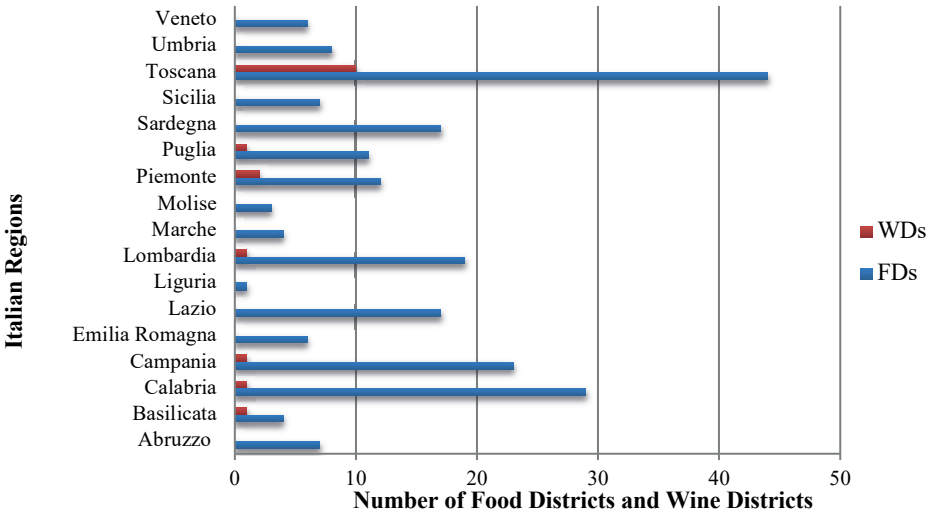
The National Law No. 205/2017 amended prior legislation on agri-food districts and introduced Food Districts (FDs) as a developmental model for the Italian agri-food sector. This law significantly propelled the formation and growth of new districts. As of April 5, 2024, there are currently 218 Food Districts in Italy.

The incidence of Wine Districts (WDs), which are areas where wine is the dominant industry, is relatively limited, making up only 8% of the total Food Districts (FDs), with the majority concentrated in Tuscany. In these regions, the territory plays a vital role as a "versatile integrator" among businesses, productive sectors, and the population. It is within the territory that local communities form through the integration of production, consumption, and the fulfillment of their needs (Sforzi, 2000, p. 186).

It is important to address some critical challenges that Protected Designation of Origin and Protected Geographical Indication (PGI) production systems face in order to maintain their competitive advantage, especially in the international arena.

Firstly, key issues include the need for protection against counterfeiting and the enhancement of traceability and transparency for consumers. Greater transparency throughout the supply chain allows for reliable product certification from the field to the table. This certification not only safeguards

Figure 2 - Distribution of Food Districts and Wine Districts in Italy (to 5 April 2024)



Source: Our elaboration on data available on www.politicheagricole.it.

producers but also protects consumers by reducing information asymmetry and enhancing the brand's reputation, as well as that of the Denomination of Origin and/or the Quality Agri-Food District.

From an institutional and organizational perspective, it is crucial to focus on the rationalization of territorial governance. As highlighted in the XXI Ismea-Qualivita Report 2023, this approach can lead to less conflictual governance, especially in areas where PDO and PGI products serve as the foundation of the local economy.

In designing a new production paradigm and overcoming the critical issues identified, useful support could come from a twin transition process of the PDO/PGI food and wine production systems favored by the implementation of Blockchain and other digital technologies. The following paragraphs will be dedicated to an examination of the literature that addressed these issues.

1.2. *Literature background: the twin transition in the agri-food chain*

The topic of twin transition in the agri-food supply chain has garnered significant attention in recent literature. Various reviews on the subject provide insights relevant to this study. According to Marvin *et al.* (2022), Artificial Intelligence (AI), big data, and digitalization possess great potential to support the transition towards a sustainable food system. This is especially

important given the complexity of agri-food systems and the vast amounts of data that require substantial computational infrastructure.

Myshko *et al.* (2024) offer a detailed overview of the literature concerning the digital transformation of the agricultural and agri-food sectors. They address several topics, including the characteristics and applications of technologies across the supply chain's nodes, environmental issues predominantly tackled by digital technologies, the identification of key stakeholders, and the sustainability outcomes of the digital transformation process. In their review, Myshko *et al.* ranked digitalization's contributions across four environmental areas: resource use reduction, environmental impact reduction, waste management, and ecosystem protection. Among the specific digital tools, the Internet of Things (IoT) was the most frequently mentioned technology in all areas, followed by Blockchain technologies.

The integration of digitalization and sustainability requires not only changes in functions and the inclusion of new actors but also improved coordination at all system levels, among networks of actors, and through their interaction channels. Checchinato *et al.* (2022) highlighted the intersection between digital applications and sustainability strategies within agri-food firms. They noted that while there is substantial academic and policy work investigating the pillars of sustainability in agriculture, only a limited number of studies link sustainability to digitalization. The primary drivers for implementing digital technologies in agri-food supply chains are largely found in the production stage (Checchinato *et al.*, 2022; Myshko *et al.*, 2024).

Specifically focusing on the support of Blockchain technology for sustainability in the food sector, Duan *et al.* (2020) pointed out that Blockchain's characteristics – such as decentralization, security, immutability, and smart contracts – have the potential to enhance sustainable food supply chain management and food traceability. However, they also identify several potential challenges, including a lack of understanding of Blockchain technology, technical difficulties, raw data manipulation, stakeholder involvement, and insufficient regulations.

Within the context of this study, Brunori (2022) discussed the twin transition towards sustainable rural digitalization, suggesting real-life experiments and emphasizing governance, rural strategies, and integrated policies. Lastly, Ciliberti *et al.* (2024) examined a case study of the Consortium for Parmigiano Reggiano, discussing the impacts of its digitalization strategy on natural resource management. They noted improvements in reducing inefficiencies and enhancing communication; however, the green pillar was not fully incorporated within a twin transition context due to limited integration of the digitalization strategy with ecological transition efforts.

1.3. *Literature background: Blockchain systems for wine supply chain and non-winery sectors*

Several reviews have connected Blockchain technology to the wine sector (Costa *et al.*, 2023; Bastard & Chaillet, 2023; Malisic *et al.*, 2023; Parry *et al.*, 2023; Luzzani *et al.*, 2021). The interest in applying Blockchain in this sector (OIV, 2021) can be attributed partly to the internal characteristics and needs of the industry and partly to the opportunities that Blockchain technology presents in addressing these needs.

Literature has primarily explored the opportunities and benefits offered by Blockchain technologies, focusing on transparency and traceability (Kramer *et al.*, 2024; Sun *et al.*, 2022; Gayialis *et al.*, 2022), as well as counterfeiting and building trust (Silvestri *et al.*, 2023; Tokkozhina *et al.*, 2022; Danese *et al.*, 2021). Some studies highlight the added value of Blockchain compared to other virtual systems and the advantages of integrating them (Pullo *et al.*, 2023; Popović *et al.*, 2021). Conversely, other literature – both in hypothetical scenarios and real-world cases – has examined the challenges of implementing Blockchain and the resources required, such as financial, human, and organizational resources (Adamashvili *et al.*, 2024; Silvestri *et al.*, 2023; Sternberg *et al.*, 2021).

Most studies adopted a case study approach, driven by the novelty of the phenomenon. These studies often link real-life experiences to theoretical frameworks developed across various disciplines. Additionally, several studies conducted surveys to gather the opinions of experts and stakeholders in the supply chain. These surveys aimed to assess the readiness for introducing Blockchain technologies, evaluate the diffusion of existing Blockchain applications among participants in the wine supply chain (Agata *et al.*, 2021), and investigate the potential benefits and obstacles (Sternberg *et al.*, 2021) when Blockchain was only anticipated or already applied in practical cases.

Most literature focuses on individual firms, particularly medium-sized enterprises and small- to medium-sized enterprises (SMEs), with integrated processes ranging from vineyards to wine production or simplified supply chains (Cuel & Cangelosi, 2020; Dicuonzo *et al.*, 2021; Longo *et al.*, 2023; Prencipe *et al.*, 2022; Richter & Hanf, 2021). These studies mostly employ a descriptive approach, which hinders the replicability of Blockchain design, structure, and procedures across different wine industries and supply chains. As Danese *et al.* (2021) noted, "the literature still lacks a clear operationalization of the Blockchain system construct, as well as a complete overview of all the relevant variables that can be used to design a Blockchain system" (p. 2).

Due to the early adoption of Blockchain technology and the limited number of real case studies available, there is no comprehensive assessment of its impacts on companies – regarding business models, effectiveness and

efficiency of inter-organizational processes, and overall performance – as well as on consumers. However, some studies have attempted to extrapolate impacts using qualitative methods (Cuel & Cangelosi, 2020).

Although the Blockchain case studies examined vary in context, they commonly consider extensive information to be digitized across the supply chain. This includes data on grape varietals used, origin areas, and cultivation processes (e.g., vineyard location, age, surface area, yield, climate, water and soil conditions, and pesticide and fertilizer applications); details about wine producers, cooperatives, integrated wineries, and transformation processes (e.g., type of winery, number of bottles produced, varietal composition, and chemical and organoleptic characteristics of the wine); as well as information on storage companies and market intermediaries (e.g., tank types, contents, storage/transportation dates, and transport distances). Additional content may include certifications and eco-labels, multimedia elements (e.g., videos and storytelling), and information about recipes, events, fairs, tastings, and wine tourism activities related to specific bottles of wine.

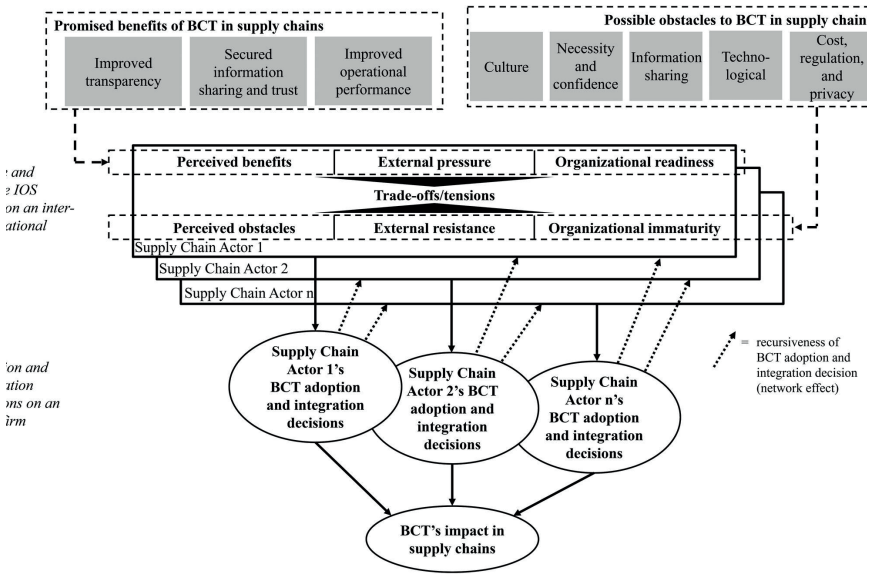
When shifting from a focus on the supply chain to considering the hypothesis of implementing Blockchain technology at the district level in the wine industry, Bastard and Chaillet's (2023) study is particularly relevant. It emphasizes the necessary prerequisites for fully leveraging the benefits of digitalization, such as establishing a strategic, collaborative, and forward-thinking approach alongside ongoing investment in technology and education. A model for inter-organizational adoption of Blockchain technologies, as proposed by Sternberg *et al.* (2021), serves as a valuable tool for exploring the hypothesis of Blockchain implementation throughout the entire wine supply chain in the case study presented below (Figure 3).

Focusing on the process of Blockchain implementation at the Quality Agri-Food District level, the work of Hacker *et al.* (2023) is particularly fruitful because it highlights the gradual progression that Blockchain consortia should follow when establishing collaborative relationship models (Figure 4).

A limited number of studies have explored the adoption of Blockchain technology within wine consortia, such as its potential implementation for the ETNA DOC wine (Agata *et al.*, 2021), or within the complex supply chains typically associated with wine production. The intricacies of the wine supply chain prior to consumer purchase arise from the many activities and actors involved, including grape growers, wine producers, bulk distributors, transit cellars, fillers/packers, finished wine distributors, wholesalers, retailers, and transporters or exporters, especially in international trade.

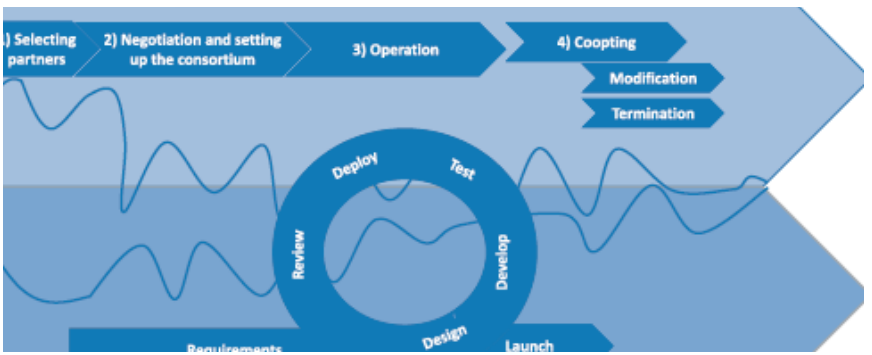
The adoption of consortium Blockchain is frequently utilized in cases where multiple organizations govern the platform, which is often accredited, to promote cooperation and address specific industry challenges (Zheng & Changmin, 2024). Additionally, consortium blockchains enhance transparency, accountability, and workflow among organizations that share

Figure 3 - Model of interorganizational Blockchain tecnologies adoption in supply chains



Source: Sternberg *et al.* (2021).

Figure 4 - Identification of staged progression of collaboration in Blockchain



Source: Hacker *et al.* (2023).

common objectives (Banerjee, 2024). In our context, as discussed below, the consortium Blockchain model appears particularly well-suited to support the management of wine flows within and beyond the Quality Agri-Food District.

Several studies have examined how technology can contribute to a more sustainable wine tourism experience among non-winery sectors within a district, as highlighted in a review by Zamarreño Aramendia *et al.* (2021). Festa *et al.* (2023) analyzed case studies of wine tourism in Italy and concluded that the level of digitalization – though limited to digital marketing tools such as websites, social media, and apps – was significant. They found that the more digitalized the wineries, the more sustainable and better performing they became; however, the opposite did not hold true. Van Huy *et al.* (2024) discovered that various factors, including technological and organizational elements (such as top management support, organizational preparedness, and employee knowledge of Blockchain technology), along with environmental factors (like competitive pressure, customer demand, and government support), positively influence the intention to adopt Blockchain technology in small and medium-sized hospitality and tourism businesses in China, where digital technology is widely utilized.

Insights from the aforementioned literature can serve as motivation for adopting Blockchain technologies within wine supply chains to facilitate the transition from a "local production system" to a "quality agri-food district," thus encouraging the dual transition of the wine sector and the district as a whole. The verification of this hypothesis will be explored through the analysis of a case study described in the following paragraph.

2. Materials and methods

The literature highlights that using a case study approach is essential for developing diverse perspectives on reality (Starman, 2013) and for understanding key characteristics of real-life events, such as the behavior of small groups, organizational and managerial processes, and the evolution of industries (Yin, 2009). Additionally, case studies offer concrete, context-dependent experiences that enhance the researcher's ability to comprehend relational dynamics, which may not easily connect to actions dictated by rules or theories (Starman, 2013). These points underscore the appropriateness of case studies in addressing our research question, which is primarily exploratory and descriptive. This method is particularly suitable for evaluating the potential application of Blockchain technologies within a specific local production context, beginning with a field analysis.

2.1. *The Case Study: Introduction*

Vermentino di Gallura DOCG is the only Protected Designation of Origin (PDO) in Sardinia that is controlled and guaranteed. It ranks among the white DOC/DOCG wines with the highest ex-cellar production prices, which stood at 215 Euros per hectoliter in 2023. This places it ninth in the national ranking, following prominent denominations such as Traminer, Franciacorta, Trento Pinot Noir, Roero Arneis, and Prosecco/Valdobbiadene, while surpassing other notable denominations like Trentino Chardonnay and Prosecco (ISMEA, 2023). The economic impact of Sardinia within the national PDO wine landscape places the region in 11th position, with an economic value of 149 million euros, 33 products, and 2,911 operators. Additionally, the local wine supply chain accounts for 26% of the agri-food economy in the region, second only to cheese, which accounts for 67%. The production system for DOP Vermentino di Gallura is characterized by a variety of players, including independent winegrowers, cooperative wineries, processing-only industries (without vineyards), pure bottlers, and fully or partially integrated industries. The Consortium for the Protection of Vermentino di Gallura consists of about 40 producers, overseeing an area of 2,500 hectares and an annual production of approximately 6 million bottles, with 80 different labels on the market. A complex regulatory framework, established in 1996 and modified in 2014, subjects all participants in the value chain – particularly those in the transformation industry – to strict compliance controls regarding wine production standards, including labeling. As of April 2024, Sardinia is home to seventeen Food Districts recognized by Masaf: fourteen rural districts, two quality agri-food districts, and one organic district, with an additional eighteen currently in the process of recognition (source: sardegnaagricoltura.it). This initiative is supported by Laore, the agency responsible for implementing regional programs in agriculture and rural development, in accordance with Regional Law 16/2014 and the related directives attached to Regional Council Resolution No. 11/8 (2020). The DOP Vermentino di Gallura Quality Agri-food District was officially recognized by the Sardinia Region in August 2024.

2.2. *Theoretical and legal aspects in the process of recognition of the Quality Agri-food District of Vermentino di Gallura DOCG*

The establishment of the Quality Agri-Food District of Vermentino di Gallura PDO was motivated by the belief that fostering strong relationships among local stakeholders is essential for wine production. This district aims to act as a catalyst for local development, a notion widely supported by

scientific literature that highlights social capital as a key factor in economic growth. Notable sources on this topic include Putnam (2000), Dasgupta and Serageldin (2000), Ostrom and Ahn (2003), and Svendsen and Svendsen (2009), as reviewed by Benedetto (2011) and Muringani *et al.* (2021). The competition among regions is influenced not only by market resources – such as tax policies, labor costs, and incentives – but also by social factors that enhance the networks of relationships within and outside companies. The creation of the district represents a natural progression in the evolution of the local wine production system, rooted in Marshall-Becattini's theory of industrial districts. While the traditional definition of an industrial district was crucial for assessing whether this specific wine-growing area could develop into a wine district, a study by Idda *et al.* (2007) confirmed that it does not entirely fit the classical Marshallian Industrial District model as defined by Becattini (1991). Nonetheless, several positive factors support the potential for the Vermentino di Gallura PDO production system to evolve into a recognized district. The theoretical framework used to identify this production system in the case study was narrower than the regulatory approach later adopted by the Sardinia Region for recognizing rural districts. While it offers a theoretical basis similar to the Marshallian District, regulatory recognition serves as a certification of a potential condition that is brought to fruition over time. Importantly, the primary goal of establishing the Quality Agri-Food District is to strengthen the network of values, associations, cooperation, and shared objectives aimed at promoting the unique qualities of the district's finished products. Access to funding from international, national, and regional sources is a secondary consideration. In accordance with the Regional Law, a multi-stakeholder approach was developed to engage a diverse range of public and private entities in discussing goals and challenges, as well as defining the programmatic interventions included in the district's first plan. The Protection Consortium of Vermentino di Gallura PDO is the leading partner and promoter of the Quality Agri-Food District, with significant participation from its wine producers, including fourteen prominent private wineries, three major social wineries operating at the regional level, a representative of winemakers, and other local institutions and associations.

2.3. *Participatory process description and its application to this case study*

The animation process involved a cycle of seven meetings between October 2022 and February 2023 and was preceded by the mapping of the stakeholders to be involved. It is not so much the number that is important, but rather the representativeness of each category of stakeholders involved:

these are actors who in various capacities are potentially interested, directly and/or indirectly, in establishing the Quality Agri-food District. In the selection process, therefore, the priority stakeholders were identified, i.e. those who could positively influence the implementation of this form of territorial governance. The first mapping allowed us to identify several key socio-economic figures involved in the participatory process, including a large number of wine companies.

The list of categories involved is reported below (Figure 5).

Figure 5 - Target groups of stakeholders invited in the animation process

The key values that guided the participatory process can be summarized as follows:

- Openness and Participation, with an approach oriented towards inclusion and listening to different needs and points of view, which was structured in a Participatory Planning process with the use of proven methodologies and widely adopted by Laore technicians.
- Representativeness: This principle emphasizes the importance of wide consultation involving economic, social, and institutional representatives from the territory.
- Inclusiveness: This involves actively engaging a diverse range of stakeholders, fostering participatory meetings that serve as platforms for discussion, listening, and learning.
- Transparency: Clear information and communication are essential to promote events and share the results achieved during work meetings.
- Co-planning and Result Orientation: The concrete outputs from each multi-stakeholder territorial animation meeting contributed significantly to developing the various sections of the Programmatic Plan. The

stakeholders alternated in leading the animation meetings, which were accessible both in person and online. Each meeting included a participant sign-in, with signatures collected through specific forms attached to a Descriptive Report submitted to the Sardinia Region. This was part of the required documentation under the implementing directives of Regional Law 7 August 2014, No. 16, to gain recognition for the District. Each meeting was structured like an extended focus group, tackling a specific theme that guided the discussions and helped identify strategies to address potential criticisms. During the third meeting, a participatory SWOT analysis was conducted with the assistance of Laore technicians. The fourth meeting focused on creating a participatory problem tree, while the fifth meeting analyzed participatory needs, allowing participants to suggest solutions to the identified challenges. By the sixth meeting, the results were summarized, and a draft of the programmatic plan for the district was presented. In the seventh meeting, a schematic Tree of Problems and Objectives was shared, along with the draft Statute and Regulations, and the collection of membership forms commenced. Laore Sardegna Agency facilitated the process by providing technical assistance and documenting each meeting to maintain transparency throughout the participatory process. Officials from the Autonomous Region of Sardinia play a crucial role during the animation days, offering vital information about relevant legislation, funding sources, the contents of the Regional Law on wine tourism, and the legal structures necessary for establishing the district.

3. Results and discussion

The participatory process highlighted the need for tools to support the districting of a local production system that requires a stronger network among local actors at various levels:

- Micro Level: Pertaining to the core producers of Vermentino di Gallura DOP.
- Meso Level: Connecting actors located upstream and downstream of this core.
- Macro Level: Considering public actors, such as agencies responsible for ensuring production compliance with established specifications. Additionally, there is a need to promote sustainable production techniques and enhance internationalization. Based on issues raised in the literature review, Blockchain technology and the digitalization process may offer solutions to some of these challenges.

The following discussion will explore the opportunities Blockchain presents for implementing the local District as it embarks on a twin transition path.

The introduction of a Blockchain combined with the digitalization of all phases of the production process could solve some of the internal problems of the system and respond to the purpose of allowing the intermediate and final consumer to verify the composition of each lot/bottle of wine along the entire supply chain from the grape growers to the retailers. The registration of the critical phases of the process within the Blockchain could make it more complicated, which causes failure to comply with production standards, and puts the consumer in a position to know the origin of the bottle as well as accessing production information. As previously reported, the type of Blockchain considered in the case study is the consortium, in which a group of members handles the control: the verification and addition of records to the Blockchain is based on a consensus mechanism by a pre-selected set of nodes.

Recently, Costa *et al.* (2023) focused on the digital transformation among family-owned low-tech SMEs operating in the Sicilian wine sector and showed that any of the investigated firms introduced a revolutionary business model innovation. These findings suggest that in the Sardinian case study, it could be useful to work on the promotion of disruptive digital business models at a single firm's level.

3.1. *The implementation hypothesis of Blockchain and digital tools of the Quality Agri-Food District of Vermentino di Gallura PDO*

The importance of expanding Blockchain boundaries is linked to its potential benefits, although for the "network effect" to occur and the benefits to be realized, a critical mass of supply chain actors adopting the technology and a disruptive socio-technical process are relevant issues (Rijswijk *et al.*, 2023; Sternberg *et al.*, 2021). The process of Blockchain and digitalization at the level of wine Quality Agri-Food District is far from being an easier and faster result.

All challenges that Bastard and Chaillet (2023) reported along the path of Blockchain implementation in the wine industry, are amplified in the reality and complexity of a District due to a wider range of interested stakeholders beyond the local wine supply chain actors who are central, but not necessarily the only ones. The need for interoperability between different systems and tools, such as various digital platforms, software, and devices to communicate and exchange data, becomes even more relevant at the Quality Agri-Food District scale. Another significant challenge in the digitalization hypothesis that is amplified within the District despite a single wine industry is the resistance to change and the lack of an innovative mindset among

all stakeholders involved within the inter-organizational system. Other challenges present in the case study are reflected in the literature (Banerjee, 2024): the lack of cooperation that impedes participants from reaching an agreement; the need for updating Blockchain structure and protocols, when the number and types of participants increase compared to the beginning.

To tighten control over the movement of grapes and wine in the case study, the hypothesis of Blockchain implementation at the district level requires adding inside the Blockchain platform a block represented by the Protection Consortium that could confirm the legality of the grape and wine production practice according to the PDO Disciplinary and the compliance with the specification for each producer.

Besides implementing a Blockchain system at the District level integrating it with other digital tools, such as electronic labels and QR codes whose benefits are envisaged at least in three spheres. First, the electronic label can be automatically translated into official EU languages known and preferred by the customer who scans the QR code. A further advantage is the possibility to update the provided information at any time: using this method, it is possible to always guarantee compliance with regulatory evolution, as well as add new content, thus avoiding the waste of physical labels and the related costs if information and data were to change. Furthermore, the QR code on the printed label does not take up much space and prevents "crowding" the back label of the wine, but it wins over the potential customer during the purchase, with certainly more captivating information. Finally, although no commercial or marketing information may appear on mandatory electronic labels to comply with the laws, wineries in the District could voluntarily choose other digital labelling and QR codes thereby opening up new engagement and marketing opportunities while maintaining the complete design of the brand/label with content linked to the QR codes (such as photos, videos, winery events, technical data sheets, awards and recognitions).

Indeed, electronic labels and QR codes provide a suitable solution for wine producers to meet the requirements of the EU Regulation. Also, the entry into force of the new EU Regulation on wine labelling (Reg. 2021/2117 amending Reg. 1308/2013) with the year of production 2024 pushes the wine industry towards greater transparency and communication with consumers. In particular, the above legislation permits that – for the list of ingredients and nutritional values – producers can choose between reporting them on the physical label or inserting them in a specific virtual space accessible via a QR code. To comply with this new regulation, wineries, as well as consortia, can exploit the potential of digital labelling and QR codes.

3.2. *Implementation hypothesis in non-winery actors within the District: the tourism valorization*

Blockchain technologies can be of great support for the involvement of non-winery operators located downstream of the production of Vermentino di Gallura PDO and provide assurance, most of all to distrustful actors, about the adoption of a common standard.

The creation of a network of relationships between the local wine and tourism sectors would make it possible to achieve a *governance of* the local system, aimed at creating an alignment between tourist supply and demand, and making the most of the wine tourism phenomenon, for the benefit of the two sectors. On the other hand, the Protection Consortium will play a fundamental role in GI tourism matters according to the reform introduced by Reg. UE 2023/2411. In essence, an institutional role is assigned to the Consortium in the promotion of "PDO tourism" by linking tourist accommodations to geographical indication products. Therefore, the Vermentino di Gallura PDO, an expression of local identity, would guide the ecological and digital transition path of the entire system that revolves around it.

In this larger implementation hypothesis, the idea would be to build a Blockchain of the Quality Agri-Food District that includes within the boundary of the system operations/operators outside the vine-wine supply chain but related to it, that remains the nucleus of the Blockchain district. The hypothesis refers to all the players that use Vermentino di Gallura wine to promote it in tourism and gastronomy, first of all in typical restaurants and agri-tourisms located in the area. All companies involved in the local wine tourism valorization should be profiled within the common platform and agree to sign the Blockchain, recording all the information necessary to trace back the wine chain; if so, they will be allowed to use a common brand of the Quality Agri-Food District.

In addition to typical restaurants and agri-tourisms located within the geographical area of the District and offering its wine, there is the possibility of including other food producers that are based on Vermentino wine as an ingredient for other types of high-quality food products. This could be the case for those pasta factories located in the territory of the Vermentino District that produce special products.

Lastly, fairs and festivals in the wine sector could be somehow linked to the District platform. This could be the case with the annual event "Benvenuto Vermentino" which aims to create awareness and promote Vermentino di Sardegna PDO through meetings and guided tastings.

In addition to extending the digital traceability and valorization of Vermentino di Gallura thanks to the Blockchain platform, a further

possibility is to introduce a Quality Agri-Food District certification, in which, as reported below, rigorous environmental, social and economic protection criteria – the pillars of sustainability are satisfied.

Therefore, the positive influence may be more difficult in a context, such as the one under study, where technology is less widespread, and knowledge and skills, technological infrastructure and Internet access are limited. However, it provides a point of reference regarding the factors on which to intervene in the study context to positively orient local non-winery actors towards digitalization.

3.3. *The twin transition: the support of Blockchain and digital tools for the sustainability of the Quality Agri-Food District*

Blockchain technology is still in its early stages and faces several challenges, particularly the significant amount of energy consumed by the technology itself and the associated implementation costs. Given these environmental impacts and economic concerns, the digital innovations achieved through Blockchain would be further justified if a broader and multifunctional application of the technology were possible, especially in environmental and social areas. One promising application of Blockchain is its potential to serve as a sustainability management tool in the wine industry, as indicated by various studies. For instance, Luzzani *et al.* (2021) reported in their exploratory study that Blockchain enables the collection of data and information crucial for monitoring and enhancing sustainability. However, to fully leverage the technology, it is essential to integrate the data collected by Blockchain with the indicators used in wine sustainability programs and certifications. Pullo *et al.* (2023) emphasized, within the context of increasing production and water footprints, the importance of integrating Blockchain with the Internet of Things (IoT) to address scalability and transaction cost challenges inherent to Blockchain.

From a political standpoint, there may be pressure to use digital tools for sustainability due to the recent EU Regulation 2024/1143, which reforms and unifies existing laws concerning the European Geographical Indications system. This new regulation recognizes and promotes sustainable practices that encompass environmental, economic, social aspects, and animal welfare. It outlines rules (Article 7) related to sustainability and allows producer groups to agree on sustainable practices for producing designated geographical indications or for other obligatory activities specified in the regulations. Moreover, this regulation grants greater autonomy to producer groups, enabling them to establish a voluntary system that strengthens their position within the supply chain. Finally, Regulation 2024/1143 supports

the digitalization of the sector, stating that "the Commission may establish and support a digital system for the inclusion of optional quality claims and schemes to promote awareness of products and schemes across the Union" (Article 79).

Additionally, according to national law (D.Lgs. 116/2020), starting from January 2023, it is mandatory for wine labels to include three environmental indications: an alphanumeric code regarding packaging materials (under Decision 129/97/EC), the specific materials used in the packaging, and guidelines for proper disposal at the end of the packaging's life cycle. Integrating VIVA indicators (air, water, vineyard, and territory) within a Blockchain platform could fulfill the goals of Blockchain technology. Given these factors, the case study presents an opportunity to advance digital and sustainable innovations within the local wine sector, beginning with the regional adherence to the VIVA Program, which currently includes only one Sardinian wine producer. Moreover, implementing the VIVA Program at the district level – which requires participation from at least 75% of the wine marketed under its umbrella – represents another pathway for assessing the district's overall sustainability performance through the combination of sustainability and digitalization. From an environmental perspective, integrating sustainability and digitalization can also be explored through a circular economy approach within the studied district. The vine and wine sectors generate several by-products, such as vine pomace, grape stalks, and wine lees, which can be utilized in various ways. In this case study, key sectors interested in utilizing these waste products include natural cosmetics, nutraceuticals, textiles and fibers, as well as natural coloring for food and fibers. The digitalization of these circular processes is considered extremely beneficial not only for tracking material flows but also for enhancing the overall environmental efficiency of the circular system.

Lastly, concerning the boost that digitalization can provide for exporting Italian wine, the ICE (Agency for the Internationalization and Promotion of Italian Companies) launched the TrackIT Blockchain project in 2022. This project aims to offer Blockchain traceability services for Made in Italy products in the textile/clothing and agri-food sectors. So far, 45 companies in the wine sector, including several from Sardinia, and 198 products have benefited from the project's support. Although only individual firms can participate in the TrackIT program, consortia could play a crucial role in facilitating the involvement of local businesses.

Conclusions

This study aimed to enhance the discussion surrounding the twin transition in the agri-food sector by examining its potential for valorizing a wine

product with a designation of origin within a Quality District. Although still a work in progress, the study provides insights for future research and its application in other sectors.

Preliminary results suggest that both environmental and digital transitions could benefit various aspects of sustainability, the local supply chain, and the surrounding territory. However, challenges are anticipated during implementation. Among the projected benefits are improved traceability of wine supply chains, which ensures the origin of production and enhances transparency for consumers. Additional advantages include the protection of the Protected Designation of Origin (PDO) supply chain from counterfeiting and the use of digital tools for the sustainable promotion of the territory. Numerous obstacles exist in this context, particularly those related to the broad and diverse processes involved in the digital transition, as well as the inter-organizational nature of tools like Blockchain.

The Blockchain consortium approach considered in this study fosters trust among enterprises and facilitates collaboration on a common standard. This represents an innovative contribution to the literature, as few studies have explored the adoption of Blockchain at the district level, rather than focusing solely on individual firms. This shifts the focus from the core of a Quality Agri-Food District – the wine supply chain – to its peripheral activities, phases, and sectors.

Future research could explore various perspectives that are valuable both in this case study and on a broader scale. One key area of investigation could involve examining the digital orientation and openness of both core and peripheral stakeholders, as well as their engagement in the twin transition process. The case study method is particularly suitable for exploring novel and complex issues and for calibrating the application of new tools in specific contexts using a place-based approach. Qualitative research methods and tools, such as those applied in this case study, are useful for understanding new phenomena, collecting primary data, and gaining experience with field techniques. Continued research in this case study may provide guidance on structuring a standard protocol that could be replicated in other settings.

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