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Exploring blockchain adoption in the italian wine industry: insights from a multiple case study

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Abstract. Modern blockchain-based product tracking systems have the potential to revolutionize the agrifood industry, ensuring transparency and accountability. The need to comply with stringent regulations and contrast frauds makes applications in the wine industry particularly relevant. However, recent studies suggest that the adoption of blockchain in the wine industry presents unique complexities and opportunities. Adopting a multiple case study approach, this paper uses data from 16 SMEs in the Italian wine industry to provide a comprehensive overview of the drivers and challenges of blockchain adoption in the wine industry. Furthermore, this study extends the literature by identifying the key requirements of a blockchain system that meets the needs of SMEs in the wine industry. This study contributes to the literature through the identification of 8 fundamental challenges and drivers of blockchain adoption in the wine industry, including companies' lack of familiarity with the technology, lack of technological skills, the importance of management vision and partnerships with technology providers. The results also clearly highlight the need to develop blockchain systems combining supply chain management and marketing objectives. Finally, this study provides useful practical implications, which can guide wineries and governments to promote the adoption of blockchain in the wine industry.

Keywords: wine industry, blockchain, SMEs, case study.

1. INTRODUCTION

The modern agrifood industry faces key challenges due to its pivotal role in sustaining the growth and development of society. This is exacerbated by globalization, which increased the complexity and risks of managing supply chains, leading to food safety issues and demands for higher quality and accountability from consumers and governments [1,2]. Agrifood companies are also pressured to build more transparent and equitable supply chains [3,4]. The adoption of advanced tracking systems may provide a solution by helping streamline information and product flows, improve coordination, and enhance transparency throughout agrifood supply chains [5,6]. Blockchain-based systems, in particular, may offer greater security, integrity, and

accountability compared to traditional ICTs [7,8]. This is crucial in tracking agrifood products, which are especially sensitive to environmental factors, including temperature or humidity, and must meet high safety standards [9,10].

From this perspective, a particularly compelling scenario concerns the adoption of tracking systems in the wine industry, which must also contend with serious counterfeiting, imitation, and label adulteration issues [11,12]. Indeed, while many agrifood products are treated as commodities, high-end wines can be considered premium products, enabling companies to focus on differentiation strategies [13–15]. Since the origin and variety of grapes play a crucial role in determining wine quality and influencing consumers' choices, producers and consumers require reliable systems to guarantee product authenticity [16,17]. This is especially true also due to the proliferation of unreliable food certification schemes, which fuel trust and communication issues between companies and consumers [18,19]. Despite this, the diffusion of advanced product tracking systems in the wine industry remains limited and it is essential to investigate the reasons explaining the low adoption rates.

However, this topic currently remains under-investigated, as most studies adopt one of two approaches. On the one hand, several articles focus on describing the impact and main advantages of blockchain-based solutions for supply chain management compared to traditional tracking systems [20–24]. These inquiries adopt a technology-centric perspective and do not consider specific applications in the agrifood industry. On the other, some papers focus on investigating the potential of advanced tracking systems for a variety of applications in the agrifood industry [5,6,25–27]. However, most studies provide purely theoretical contributions. While offering valuable insights, these articles typically stress the novelty and benefits of blockchain solutions over implementation challenges and business implications.

Indeed, it is only recently that the first studies focusing on the adoption of blockchain-based systems in the wine industry started to emerge [11,17,28–30]. These investigations suggest that the adoption of blockchain in the wine industry entails significant managerial and organizational complexities which require careful analysis. For example, Brookbanks and Parry [30] show how the use of blockchain systems does not remove the need to implement trust-building processes between wineries, partners, and consumers. Galati et al. [29] suggest that effective blockchain adoption depends on wineries' ability to invest and redefine knowledge management processes within the organization. Cordeiro and Olsen [31] investigate the differences in the diffusion of blockchain in European and Chinese wine value chains, emphasizing the influence of the environment and the international context.

Despite the contributions, most of the articles focus on isolated success stories [11,17,29]. Due to the limited diffusion of blockchain in the wine industry, this helped provide much-needed evidence of how the adoption of advanced tracking systems may affect wineries' business models and performances. At the same time, this led to a somewhat biased perspective, emphasizing the benefits and positive outcomes over complexities. This highlights a gap in the literature related to the lack of studies investigating the challenges of blockchain adoption in the wine industry, and the in-depth analysis of the requirements that tracking systems must possess to meet the needs of actors in wine supply chains. This study aims to help bridge this gap and offer a new perspective by analysing the challenges, drivers and requirements of blockchain-based solutions in the wine industry.

Additionally, we note how most studies investigating specific applications of tracking systems in supply chains focus on large-scale projects, involving multinationals, tech companies and several partners around the world [32–34]. This approach is not suitable for the wine industry, due to the prevalence of SMEs and local productions in the sector. Thus, we try to help bridge this gap by providing an empirical investigation of the drivers and challenges of blockchain adoption for SMEs in the wine industry. Ultimately, we aim to answer the following research questions:

> What are the drivers and challenges of adopting blockchain-based systems for SMEs in the wine industry?
>
> What are the requirements for a blockchain-based system to meet the needs of SMEs in the wine industry?

To answer these research questions, we adopt a multiple case study approach, focusing on the case of the Italian wine industry. Specifically, we investigated companies' perception of blockchain solutions by performing semi-structured interviews with the managers of 16 Italian wineries. Then, we use thematic analysis, supported by a three-step coding process, to identify overarching themes and develop the results. In selecting the cases, our primary goal was to obtain a detailed picture of the current situation of traceability and blockchain adoption in the Italian wine industry.

The originality of the study lies mainly in two aspects. It is one of the first studies to investigate the problem of blockchain adoption in the agrifood industry concerning a specific application, namely product tracking in the wine industry. Second, this study does

not analyse single cases, but adopts a multiple-case study approach, leading to a nuanced perspective introducing new relevant elements into the debate.

Finally, this study has important theoretical and practical implications. From a theoretical perspective, it effectively complements the results of previous literature, by providing an in-depth analysis of key managerial and organizational factors influencing wineries' decision to adopt blockchain technology. It also advances the theory by analysing the requirements that a blockchain system must possess to meet the needs of SMEs in the wine industry. In terms of practical implications, this study helps wine companies assess the opportunities and implications of adopting blockchain. Furthermore, it provides policymakers and governments with suggestions on how to support the diffusion of advanced tracking systems in the wine industry.

The rest of the paper is organized as follows: the next section provides a brief yet rigorous review of available literature. Then, we describe in detail the case study and thematic analysis methodology. Next, we present and discuss the results. Finally, we conclude and provide some useful theoretical and practical implications.

2. LITERATURE REVIEW

In recent years, blockchain technology has been increasingly applied to supply chain management. In the agrifood industry, the adoption of blockchain-based tracking systems enables real-time monitoring of products throughout the supply chain, enhancing safety, transparency, and accountability [6,26,27]. This is crucial as most agrifood products deteriorate rapidly and are sensitive to changes in environmental parameters such as temperature or light exposure, which could undermine their quality in the passage from production to consumption [9,35]. Furthermore, product tracking is also essential to help agrifood companies demonstrate compliance with the stricter standards that institutions recently enforced to ensure accountability of agrifood supply chains [36,37]

These advantages may be particularly felt in the wine industry, which is also affected by serious fraud and counterfeiting issues, and product tracking systems are crucial to safeguard companies and allow consumers to make informed purchasing decisions. Furthermore, the ability to provide reliable information about grape origin and production methods may help wineries implement differentiation strategies, strengthening their brand identity and increasing margins [15,38]. On this note, Bandieri and Castellini [14] explore the impact of different strategic orientations on the performance of Italian wineries, showing how the most successful companies adopt a differentiation strategy. Similarly, Del Rey and Loose [39] highlight that the growth of the global wine market is driven by premiumization, reinforcing the importance of differentiation strategies.

As for the crucial role that blockchain technology may play in the wine industry, Malisic et al. [12] note how the development of global wine value chains has emphasized the role that blockchain can play in ensuring traceability and safety. Adamashvili et al. [40] used an agent-based simulation model to show how blockchain adoption can help wine companies not only improve traceability but also assists detection of potentially harmful products. At the same time, recent studies suggest that blockchain adoption entails significant managerial and organizational challenges.

Among these, Luzzani et al. [16] show how the majority of companies have only basic knowledge of blockchain. Interestingly, this holds even for wineries possessing a sustainability certification, suggesting that companies are not yet thinking of blockchain as a means to complement certification mechanisms. Furthermore, in their analysis of traceability systems in the Italian agrifood industry, Corallo et al. [41] confirm that Italian agrifood companies are interested in traceability issues, but are not aware of the profound connections between digital technologies and product tracking systems.

Danese et al. [11] investigate whether blockchain-based tracking systems can effectively overcome the limitations of existing counterfeiting measures in the wine industry. The authors focus on how different design choices influence the level of counterfeiting protection guaranteed by specific blockchain solutions. Results show that the level of protection obtained depends on the information feeding and reeding processes and that companies may design such mechanisms balancing costs and safety targets. In general, more frequent updates and timely controls increase the level of protection, to the detriment of complexity and costs. Thus, companies offering low-priced wines may choose to implement limited protection mechanisms and focus on preventing consumers from assuming that low prices entail a low-quality product. On the opposite side, companies producing high-end wines may adopt tighter protection mechanisms to enhance company reputation and leverage the unique qualities of their products on the market.

Overall, several theories and conceptual models have been used to analyse the challenges and opportunities of adopting blockchain systems in the wine industry.

Galati et al. [29] and Silvestri et al. [28] move from the Resource Based View (RBV) to analyse the enablers

of blockchain technology adoption in the wine industry. Both studies investigate how the development of knowledge and capabilities may help wine companies gain a competitive advantage from the use of blockchain-based tracking systems. In this, both studies combine the RBV with the theory of dynamic capabilities, stressing how the adoption of disruptive technology such as blockchain requires wineries to change their knowledge acquisition and management processes. Results suggest that one of the main challenges of blockchain adoption is wineries' lack of technological skills. However, while Galati et al. [29] emphasize the role of management in bridging such knowledge gaps and suggest that wine companies can effectively delegate key innovation activities to technology providers, Silvestri et al. [28] propose that targeted hiring and partnerships with tech companies can help wine companies develop the capabilities required to integrate blockchain technology into the business internally. Interestingly, the study also proposes that the adoption of blockchain solutions may be favoured by vertical integration processes. As for the ability to gain competitive advantages, Galati et al. [29] suggest that the adoption of blockchain systems does not lead to direct savings, but can effectively enhance brand identity and wineries' marketing efforts. Silvestri et al. [28] instead propose that blockchain helps firms control processes and information flows. In addition to favouring vertical integration of the supply chain, this helps firms to ensure security, transparency and accountability of the supply chain.

On a different note, Tiscini et al. [17] investigate the implications of blockchain adoption on business model sustainability in the agrifood industry focusing on an exemplary case in the wine sector. The authors refer to the Value Triangle Business Model Canvas (VT BMC) framework, a conceptual model expressly designed to consider the sustainability aspects underlying a business model. Results suggest that blockchain adoption can help wineries improve their value proposition by providing reliable information to consumers. In turn, this can push consumers to promote sustainability practices throughout the supply chain. Furthermore, increased transparency of the supply chain allowed the company to define customers' education initiatives, aimed at increasing consumer awareness of product features. At the same time, the introduction of blockchain entailed set-up costs due to staff training and the need to update information systems. However, these could be offset by improved efficiency in business transactions and simplified accounting and reporting activities.

Tackling the problem from a broader perspective, Cordeiro and Olsen [31] provide an empirical assessment of the effectiveness of blockchain adoption as an anti-counterfeiting and traceability tool in the wine industry. Referring to the UTAUT theory, the study identifies key factors for technology acceptance, including perceived usefulness and ease of use. Results suggest that companies expect blockchain to significantly influence the development of the wine industry, although reservations regarding set-up costs and efficiency remain. Additionally, producers seem concerned about the time and knowledge needed to adopt the technology, while traders' perspective is more nuanced and depends significantly on the local and international business environment.

Brookbanks and Parry [30] investigate how blockchain-based platforms might affect trust and trust-building processes in buyer-supplier relationships in wine supply chains. The authors show that blockchain does not remove the need to develop trust-based relationships between partners and perform physical controls on products. At the same time, the use of a shared blockchain platform helps to reduce information asymmetry, duplication of information, and errors caused by the management of paper documents.

Overall, available literature suggests that blockchain technology could play an important role in the development of the wine industry, increasing security, and transparency and favouring the establishment of trust relationships with partners and consumers. At the same time, several challenges remain and the full implications of blockchain adoption remain unclear. In an exploratory study on the impact of blockchain technology on the sustainability of companies in the wine industry, Luzzani et al. [16] show that wineries' familiarity with blockchain remains limited and that only a marginal share of companies is willing to invest in blockchain systems in the coming years. Kang et al. [42] developed a Stackelberg Game model to evaluate the impact that a blockchain product tracking system could have on wine supply chains. Comparing different equilibrium conditions, the authors conclude that the implementation of a blockchain system leads to an increase in wine prices depending on consumers' traceability preferences and privacy concerns.

Indeed, most studies investigating blockchain adoption in the wine industry empirically focus either on limited applications, or isolated success cases. Thus, the requirements necessary for a blockchain system to meet wine companies' needs are currently under-investigated. In this study, we move from previous literature results and try to gain a deeper understanding of the mechanisms and implications of blockchain adoption in the wine industry, by analysing the perception of companies in the Italian wine industry.

3. METHODOLOGY

3.1. Research design

This study aims to provide empirical evidence of the drivers and requirements of blockchain adoption in the wine industry, using a multiple-case study approach. Case studies are particularly suited for exploratory research, especially when analysing emerging phenomena for which no established theoretical framework is available [43]. From this perspective, case studies enable the empirical investigation of the key factors driving a phenomenon, even in the absence of established measurement models that would allow for quantitative analysis [43]. Indeed, the nascent literature on blockchain adoption in the wine industry effectively resorted to the case study approach, as the novelty of the phenomenon and the limited diffusion of blockchain make quantitative analysis impractical [11,17,30]. This is also appropriate due to the prevalence of SMEs and micro-enterprises, which navigate a delicate balance between traditional business models and the push for technological innovation driven by the evolving needs of stakeholders. In this, case studies allow us to grasp nuances in companies' perceptions, enabling the representation of complex phenomena. Specifically, in this study, we opted for a multiple-case study approach to advance the literature and provide a novel perspective. Indeed, multiple case studies allow for the consideration of multiple sources of evidence and enable cross-case analysis, which enhances the reliability of the results and allows to address multiple explanations [43]. Furthermore, in analysing each case, we opted for a holistic design. Holistic case studies focus on a single unit of analysis. This is appropriate when it is not possible to identify relevant sub-units of analysis [43]. We chose to adopt a holistic design as we focus our attention on SMEs, which can be considered single business units.

Consistent with the case study design, we adopt a theoretical sampling technique. Different from statistical sampling, this is effective when the number of observations is limited. Also, theoretical sampling is based on a replication logic aimed at increasing the consistency of the results [43]. For data analysis, we use an abductive approach. This means conducting case studies moving from an initial understanding of the theory. This allows to identification of key themes while highlighting novel results [44,45]. Figure 1 summarizes the key features and steps of our research. The subsequent sections provide more details on data collection and data analysis procedures respectively.

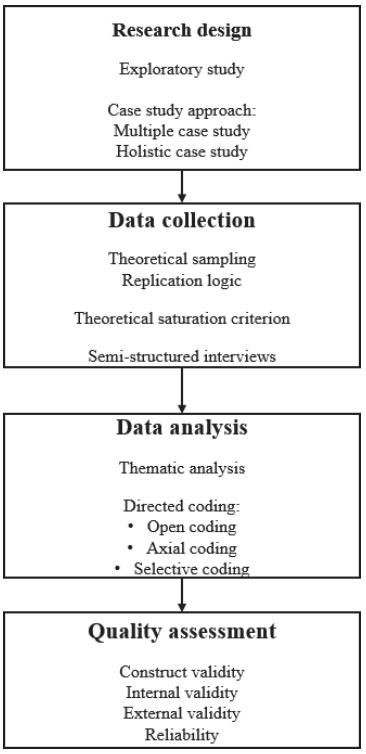

Figure 1. Research design and methodology.

3.2. Data collection

The preliminary step of data collection is the identification of data sources, which requires the definition of appropriate case selection criteria [46]. Thus, we chose to focus on the Italian wine industry, which is among the most relevant globally and is characterized by the variety of its products, which range from low-priced to high-end wines [16,29]. This makes the Italian wine industry the ideal scenario to investigate the nuances and complexities entailed in the development of blockchain solutions. Second, we chose to focus on SMEs, which represent the majority of Italian wine companies [47], and thus allow us to better analyse the current situation regarding companies' perception of blockchain technology. It is important to note that we chose not to focus solely on companies already using blockchain systems, for two main reasons. First, the literature already offers authoritative studies analysing exemplary cases of blockchain adoption in the Italian wine industry [11,28,29]. Second, our objective was precisely to move beyond the analysis of these exceptional cases and provide a more realistic representation of the overall state of blockchain adoption in the Italian wine industry. To this end, we gathered and analysed the perceptions of Italian companies regarding the

challenges and opportunities associated with adopting advanced tracking systems.

To ensure that the selected companies met these criteria, we moved from a database of Italian wine companies identified by the ATECO code. This is an identifier assigned by the Italian government to classify companies by industrial sector. Then, we distinguished between SMEs and larger companies by considering the information on the revenues and number of employees if available. Next, we chose to consider only companies possessing an active website and e-commerce service, aiming to select firms with a good level of familiarity with digital technologies. Subsequently, we selected only companies producing at least one certified wine, trying to include firms deeply invested in product traceability issues. Finally, we reached out to the remaining companies via email, explaining the objectives of the study and proceeding with those who agreed to take part in the investigation.

Following Dul and Hak's [46] suggestions, we provide multiple sources of evidence, to highlight patterns, create chains of inferences, and generalize findings.

Operationally, we adopted the criterion of theoretical saturation, stopping when the analysis of subsequent cases did not provide new elements [48]. Ultimately, we analysed 16 cases. We collected information performing a semi-structured interview with a manager from each of the selected companies. These allow the researcher to focus the analysis on key themes while allowing the interviewee to introduce new elements of debate [45]. The interviews were conducted between May and July 2023. Each interview lasted approximately 45 minutes and was structured as follows. An introductory part, aimed at collecting information on the organization, the business model, and the core activities. The second part focused on the analysis of regulations, standards, and traceability in the wine industry. The final part focused on blockchain applications, possible advantages, and challenges. We deemed sufficient to conduct a single interview for each company, as due to the small size of the companies, the management proved to possess a holistic view of the company's characteristics, objectives, and strategies, representing the most authoritative and reliable source of information available. To ensure data triangulation and complement managers' insights, we also gathered information from the companies' websites and any available document. Specifically, we analysed the websites and official documents in search of information regarding the use of blockchain technology, the companies' stance on traceability issues, certified products, and certification processes, in line with the topics discussed during the interviews.

3.3. Data analysis and quality assessment

Data were analysed using thematic analysis. This qualitative methodology is particularly useful for performing cross-case comparisons, highlighting similarities and enabling pattern matching [49]. Subject to the interviewee's consent, each interview was recorded and transcribed. This resulted in a 94-page document, used as a starting point for the coding activity. In this, we followed the three-step process suggested by Corbin and Strauss [50]. In the first step of open coding, we carefully scanned the transcript of the interviews to assign first-level codes. These are descriptive labels, useful to highlight key passages of the text. In the second step of axial coding, we merged codes establishing logical connections, to define categories. These are units of analysis characterized by a higher level of abstraction and are the first step that leads to the identification of themes. Finally, in the third step of selective coding, we refined the categories to identify patterns and create chains of evidence leading to theory testing. To ensure reliability, two researchers independently performed the coding activity, moving from a shared understanding of previous literature. Then, a third researcher acted as a mediator to help reach an agreement on the definition of the main themes and explanations.

We conclude this section by providing some information on the criteria we considered to guarantee the robustness and replicability of the results. We refer to the four main criteria illustrated by Yin [43] and discussed in numerous relevant studies [49,51,52]. Construct validity evaluates how accurately the results of a case study answer the research questions. To ensure construct validity we resorted to data triangulation, i.e., using multiple sources of evidence.

Next, we used coding to extract key themes and create chains of evidence. Finally, we asked respondents to review their answers and provide feedback or clarifications.

Internal validity considers the strength of the causal relationships allowing the researchers to make inferences. To enhance internal validity, we first performed within-case analysis and then moved to cross-case analyses to identify patterns and make logical inferences. External validity concerns the extent to which the results of a case study can be generalized to similar contexts. We addressed this issue by adopting a multiple-case study approach and by following a replication logic in the selection of cases. Finally, reliability considers the consistency and replicability of the findings with respect to the research questions. We aimed to achieve reliability by following a strict case study protocol, and by performing a rigorous coding activity.

4. RESULTS

4.1. Descriptive analysis

The selected companies produce between 18.000 and 230.000 bottles annually, and perform all production activities, from grape cultivation to bottling, internally. Each company produces at least one wine with IGP, DOC, or DOCG certification. Additionally, five companies hold organic certification, confirming the importance of product traceability, both to meet regulatory requirements and as a marketing tool. The permanent workforce ranges from 4 to 30 employees, with up to 15 temporary workers hired during peak periods, such as harvest season. The owners also act as general managers, shaping the company's strategy and value proposition, while frequently overseeing key production processes themselves. Alternatively, each company employs a production manager responsible for supervising the transformation process, as well as an oenologist. Furthermore, all the companies hired a sales manager, who handles social media and customer relations, indicating an awareness of market trends and a willingness to strengthen customer relationships. Notably, firms are utilizing new sales and communication channels, including digital platforms, while focusing on high-quality wines with unique features and actively promoting their brand identity.

The companies are distributed across Italy: 5 are based in Northern Italy, 3 in the central region, and 8 in the South. Interestingly, even if only one company, located in the South, currently uses a blockchain tracking system, overall knowledge of the technology appears to be higher among the companies in the North. Finally, only three respondents were women, despite women being part of the management teams in nearly all the companies. Table A1, in the appendix, provides information for each respondent. The names of the companies are indicated only for those that have provided consent.

4.2. Thematic analysis

In this section, we present the results of the thematic analysis, which led to the identification of eight main themes regarding blockchain adoption in the wine industry. These findings support and expand previous literature results and enable the definition of the key requirements necessary for the development of a blockchain-based system that meets the needs of SMEs in the wine industry. In introducing the main themes relevant to the adoption of blockchain technology, we begin by framing companies' perception of blockchain within the broader context of technological innovation management within the companies. From this perspective, the first theme to emerge is the limited familiarity of companies with blockchain technology. Indeed, among the 16 companies interviewed, only 5 had a clear understanding of the technology and its potential applications for product tracking in the wine industry. Furthermore, only one company currently uses a blockchain-based tracking system, while the other 4 only searched for information, scouting the market in the hypothesis of a future investment. As for the remaining 11 companies, their knowledge of blockchain varies, as some companies show relative awareness of technological developments, while others claim to have only basic information. Consistently, we notice a strong difference in perception between the company that adopted a blockchain-based solution and the others. The manager of the company that uses blockchain states: "*[blockchain adoption] was a fundamental step, to improve business performance and provide guarantees to customers*". On the contrary, scepticism remains among other companies, as witnessed by one of the managers who explains: "*I've heard about it, it's certainly interesting but we need to understand what advantages it can bring or if it's just a temporary trend*".

In investigating the reasons behind this scepticism and companies' limited understanding of blockchain, we introduce the next theme, concerning the lack of technological skills. Results show that one of the shortcomings of wineries is the lack of advanced technological capabilities. Only five companies hired IT or technology specialists, and only two companies have a technology management team. In contrast, all companies pay great attention to aspects related to quality and communication, hiring marketing specialists. This suggests that companies may not consider technological innovation a priority at present. As explained by one of the managers: "*For us, the authenticity of the product is very important [...] even if we use advanced technologies, we make sure to follow the tradition at each step*". On a different note, results highlight the difficulty of companies in hiring qualified personnel. One of the managers complains: "*It is difficult for us to hire, say, an engineer, for two reasons. First, it would be a non-negligible cost, and second, it is difficult to find engineers willing to work in a small company in the agrifood industry*". Furthermore, another company explains "*We can't find young people with technical skills willing to work with machinery in the fields*".

Consistently, another key theme concerns costs. Possessing limited resources, SMEs must carefully evaluate investments, and managers' scepticism towards blockchain technology can be partly explained by the diffi-

culty of correctly assessing costs and benefits. As effectively summarized by one of the managers: "*Investing in blockchain technology seems to entail significant costs [...] then we would have to hire qualified personnel and change all our IT systems*". This is a significant obstacle for small wineries, which due to their limited knowledge, could also be underestimating the benefits associated with blockchain implementation. The manager of the company using a blockchain-based traceability system explains: "*It was certainly an important investment, but then we realized that our management costs have significantly decreased [...] previously we wasted a lot of time managing the information, now we have everything available and the advantages are clear.*"

Moving to the fourth main theme, results highlight the over-reliance of companies on management vision and external technology providers as drivers of innovation. The lack of specialists within the company places the responsibility of fostering innovation on the management. Among the companies in the sample, those adopting advanced technological solutions are characterized by the strong determination of the management to pursue innovation goals, as evident from the following quote: "*Product improvement must go hand in hand with technological progress*". However, managers do not always possess the means and foresight to foster technological innovation in the company. It is in this scenario that external technology providers play a pivotal role, offering agrifood companies technological solutions tailored to their needs. As illustrated by one of the companies "*We have an advanced weather monitoring station, which was proposed to us by an external provider [....], and they helped us implement the system and make it work*".

After examining companies' stance on technological innovation and their perception of blockchain technology, we take a step forward and investigate the role that blockchain could play in the wine industry. First, we highlight the importance of digital solutions for supply chain monitoring and control. Companies are deeply concerned with traceability issues and with the need to comply with strict national and international regulations. One of the managers interviewed explains "*Every step is monitored [....], we must provide the government with precise information on the grapes, on the production processes and on what we sell*". Furthermore, given the prevalence of counterfeiting phenomena in the global wine industry, companies feel the need for innovative solutions capable of ensuring transparency and safety. As emerges from the interviews: "*Unfortunately counterfeiting is a problem in the wine industry and depends on many factors*". In this scenario, digital technologies can offer a solution. The Italian government developed the National Agricultural Information System (SIAN) to monitor and help companies in the wine industry. In essence, the SIAN is a digital platform allowing the government to control wine production. Overall, companies are convinced by the need to use digital technologies to increase transparency and accountability in the wine industry, but at the same time highlight the shortcomings of current solutions. One of the interviewees explains "*The government provides a valid control mechanism, but we need systems that allow us to manage the entire supply chain and also evaluate product performance*".

This passage allows us to introduce two, deeply intertwined, themes. First, the firms observed a recent shift in the market and consumer preferences. This led companies to emphasize marketing and communication. The prevailing opinion among managers is that: "*Consumers have become much more selective, drinking wine has turned into an experience [....] so, we must be able to stand out among the competition*", and more: " [...] *it is important to know how to promote the product, demonstrate its authenticity to consumers*". Consistently, 14 of 16 companies recently hired a marketing or social media specialist to enhance brand identity and customer awareness. As for the second theme, management expresses a strong interest in digital product tracking solutions that can help the company not only monitor the supply chain but also provide new opportunities to interact with the customers. As highlighted by one of the managers: "*It would certainly be useful to have a digital tool allowing us to promote the qualities and tell the story of the products directly to consumers*". Some executives also highlight how this could enable new strategies. Indeed, following market trends, several companies started to focus on the production of high-end local wines. Managers explain that these are less prone to imitation, generate higher margins, and help the company differentiate itself from competitors. At the same time, companies highlight the difficulty of making this type of product known to less experienced consumers. From this perspective, the use of blockchain-based tracking systems could offer SMEs in the wine industry a viable opportunity to make their products known to a larger share of consumers.

In light of the arguments presented so far, we can now introduce the last main theme, which also represents one of the most relevant results of this investigation. Indeed, evidence confirms the great potential for the development of blockchain solutions in the wine industry, from two complementary perspectives. These are the development of blockchain tracking solutions both for supply chain management, and marketing purposes. Overall, the literature seems to consider

Table 1. Overview of the main findings from the thematic analysis. Drivers and challenges of blockchain adoption in the wine industry.

Themes	Driver/challenge
Lack of familiarity with blockchain	Challenge
Lack of technological skills	Challenge
High investment costs	Challenge
Reliance on management support and technology providers	Both driver and challenge
Traceability as a supply chain control mechanism	Driver
Change in market and consumer preference	Driver
Traceability as a marketing opportunity	Driver
Blockchain to combine control and marketing goals	Challenge

these aspects as two distinct issues. Our findings suggest instead that SMEs in the wine industry require integrated solutions allowing them to monitor all stages of the supply chain, from production to sales. Specifically, firms need solutions that allow them to increase transparency and accountability of the supply chain, guaranteeing safety, compliance with regulations, and authenticity of products. Thus, SMEs could reconcile supply chain control and marketing objectives, building relationships of trust with governments and consumers. Table 1 provides an overview of the main themes.

5. DISCUSSION

Following the thematic analysis, in this paragraph we analyse the results in light of previous literature, highlighting elements of continuity, differences, and novel insights. Thus, we leverage the knowledge obtained to identify the requirements that a blockchain-based system must possess to meet the needs of SMEs in the wine industry.

We move from the first theme to emerge from the thematic analysis. Results show that wineries are relatively unfamiliar with blockchain technology. This is consistent with Luzzani et al. [16] and Corallo et al. [41] who confirmed that, although Italian wineries are interested in product tracking, they show little familiarity with blockchain and do not perceive the connection between the technology and certification schemes. This leads to the definition of the first requirement, which is the need to increase wineries' familiarity with blockchain technology. From this perspective, government intervention can prove decisive, to foster strategic partnerships between agrifood companies, research institutions, and technology providers.

Moving on, results show that another key element to explain the limited diffusion of blockchain in the wine industry is companies' lack of technological skills. This aligns with previous findings by Silvestri et al. [28], who stress the need to enhance the technological skills of employees, invest in hiring IT specialists and rethink knowledge creation systems within the firm. In this scenario, we provide an additional element, showing how the development of the technological skills of firms is hampered by the difficulty of attracting qualified human resources. Results show that companies struggle to find both machine operators with good technical skills and technological specialists willing to work for SMEs in the wine industry. Furthermore, companies are discouraged by the high costs of hiring and training human resources. This leads to the identification of a second requirement relating to the need to develop the technological capabilities of SMEs in the wine industry. To this end, government actions are needed to set up training programs and support investments. Furthermore, schools and universities can contribute through the training of new professional figures, combining technological expertise with a focus on the agrifood industry.

The lack of technological skills connects to two relevant issues, namely the attitude of top management towards technological innovation, and the role of technology providers. Results confirm these are two primary drivers of technological innovation for SMEs in the wine industry. Investigating cases of blockchain adoption in wineries, Galati et al. [29] and Silvestri et al. [28] note the essential contribution of top management in defining objectives and carrying forward the innovation project despite the high costs. In our investigations, we noted a significant difference in attitude between the manager of the company who has chosen to adopt blockchain technology, and the owners of other companies, who are more sceptical and show a stronger attachment to traditional business practices. Thus, the third requirement for the adoption of blockchain technology in the wine industry is the support of top management.

Regarding technology providers, several studies highlight their pivotal role in assisting wineries to set up blockchain-based product tracking systems [11,29,30]. At the same time, papers precisely focusing on examining the dynamics of such partnerships are currently lacking. Also, available literature seems to focus on the advantages provided by these collaborations, while the potential negative effects are often overlooked. Indeed, we argue that, although interaction with external partners can help agrifood companies become familiar with blockchain technology, and fill their skill gaps, over time this can cause a stagnation of companies' technological skills and increase their dependence on external providers. However, the results do not allow us to move beyond

this tentative explanation, and we stress the need for future studies on the topic.

The next theme we analyse concerns costs. Literature confirms how high investment costs are one of the major concerns of managers of SMEs in the wine industry when considering investments in blockchain technology [11,35,42]. Our findings suggest how this issue may be exacerbated by executives' difficulty in assessing the costs and benefits of blockchain adoption. This is caused by multiple factors, including the company's lack of familiarity with blockchain, low technological skills, and top management scepticism. Thus, we advance that a fundamental requirement for the diffusion of blockchain technology in the wine industry is the development of simple-to-use and low-cost solutions, tailored to the needs of small wineries. Danese et al. [11] demonstrate that blockchain tracking systems can be designed to balance cost and complexity depending on performance needs, enabling cost-efficient solutions.

After examining the key drivers and challenges of blockchain adoption by SMEs in the wine industry, we may reflect on how product tracking systems affect companies' business models and performance.

The literature agrees that the main applications of blockchain in the agrifood industry focus on product tracking. This is particularly relevant for two reasons. First, agrifood products are highly sensitive to environmental factors, which makes them prone to deterioration, affecting quality and threatening consumers' health. Second, the agrifood industry is heavily regulated, with laws and standards aimed at ensuring transparency and accountability. In this context, blockchain tracking systems can provide a crucial advantage in helping agrifood companies comply with regulations and access the market. This also holds in the wine industry, where blockchain technology could be effectively employed to enhance transparency and support supply chain management [12]. The results of this study confirm this thesis, showing how SMEs in the Italian wine industry are invested in product traceability issues and require innovative solutions allowing them to comply with regulations while improving supply chain management. Indeed, factors such as provenance, grape variety, and cultivation methods significantly impact wine pricing and consumer perception. Furthermore, differently from most agrifood products, high-end wines are premium items often produced in limited quantities. This allows wineries to invest in developing a stronger brand identity and enhance their marketing efforts [15]. At the same time, this exposes the wine industry to severe counterfeit and label adulteration issues [11,12]. Consistently, the results of this study show how SMEs in the Italian wine industry perceived a change in the market and consumer preferences. For this reason, wineries began to execute differentiation strategies, focusing on the unique characteristics of the wines while trying to build stronger relationships with consumers.

Overall, these considerations allow us to introduce the last requirement for the development of an effective blockchain tracking system tailored to the needs of SMEs in the wine industry. Specifically, we argue that issues of traceability as a supply chain control mechanism, and as a marketing opportunity should not be considered separately. Instead, results show how wineries need integrated solutions, capable not only of supporting product tracking in the production phase but also of providing a competitive advantage on the market. Thus, blockchain systems must help businesses comply with regulations, build more secure supply chains, and establish stronger relationships with consumers. Table 2 provides an overview of the requirements we identified throughout the discussion.

Finally, Figure 2 provides an overview of the main findings, and illustrates the connections between drivers, challenges, and requirements of blockchain adoption in the wine industry. Representing opportunities and enablers, drivers also allow us to identify challenges and obstacles to overcome. For example, management support and collaboration with technology providers can play a pivotal role in driving the adoption of blockchain technology but can also lead wineries to over-rely on management vision or the contribution of external partners. Furthermore, this helps explain wineries' lack of familiarity with blockchain technology. The analysis of drivers and challenges allows the identification of key requirements that a blockchain-based tracking system must possess to meet the needs of companies in the wine industry. These include both organizational and technological aspects. For example, the lack of technological capabilities and the unfamiliarity of wineries with blockchain technology leads to the need to raise companies' awareness, overcome dependence on management vision and external knowledge, and foster the development of advanced skills. At the same time, high investment costs and the possibility of combining supply chain control and marketing objectives lead to the need to develop simple-to-use, low-cost blockchain systems, which enable control throughout the supply chain and also offer businesses new ways to interact with customers. Finally, Figure 2 connects the requirements to the interventions necessary to develop effective blockchain tracking systems. These invite us to consider the contribution that government institutions can provide and to reflect on the design of modern blockchain solutions.

Table 2. Overview of the requirements and interventions needed to develop an effective blockchain tracking system for the wine industry.

Requirement	Interventions
Need to increase companies' familiarity with blockchain	Partnerships between wineries, research institutions, and technology providers
Need to develop companies' technological skills	Government support to fund training programs and elicit investments Training of new professional figures
Need to develop low-cost blockchain systems	Design blockchain systems balancing complexity, performance, and cost
Need to enable supply chain monitoring and control	Design blockchain systems that help companies comply with regulations and contrast fraud
Need to consider the potential of blockchain traceability systems as marketing tools	Design blockchain systems that help companies market their products and interact with consumers
Need to combine supply chain management and marketing goals	Design blockchain systems that integrate control mechanisms and means to interact with consumers

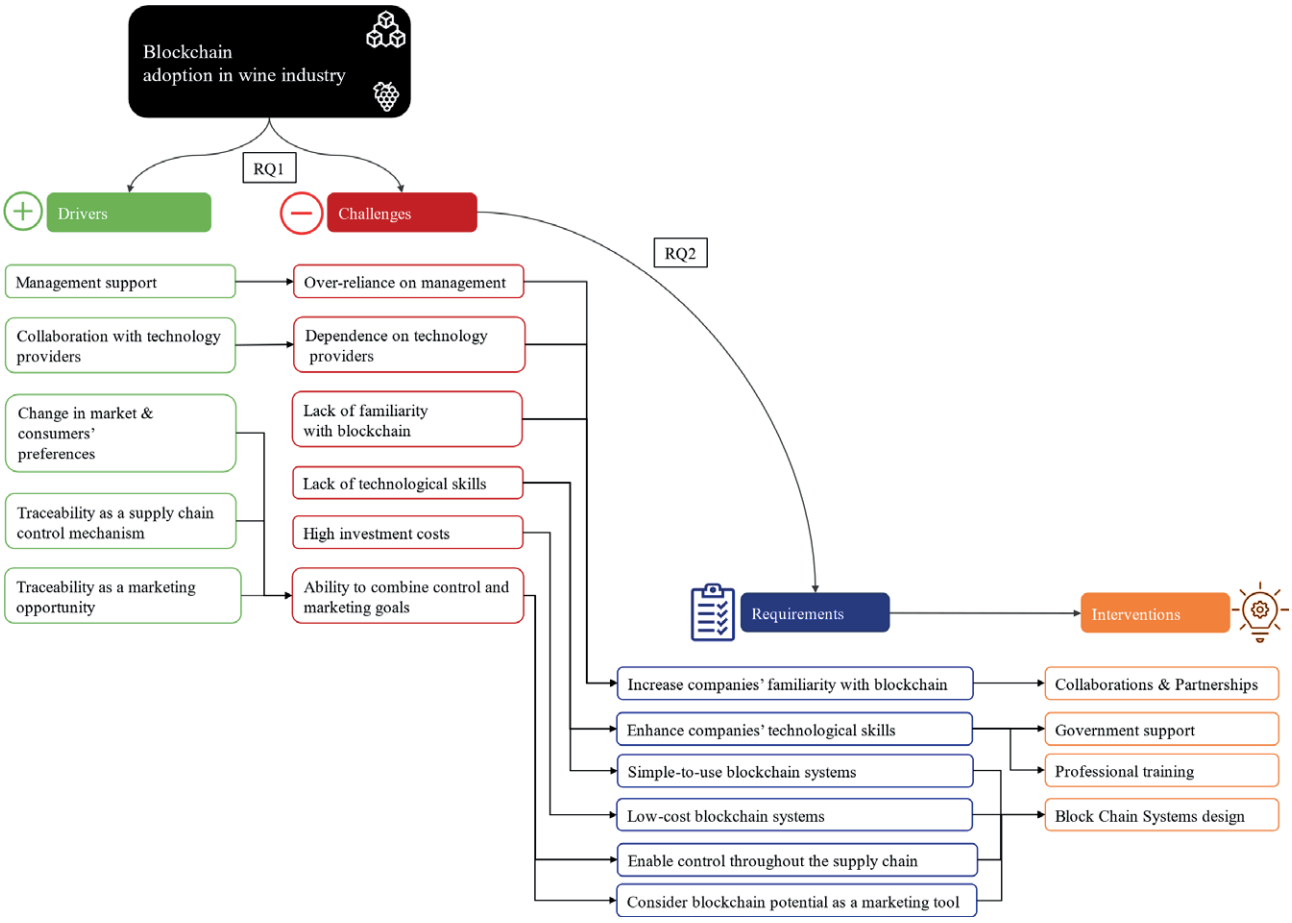

Figure 2. Drivers, challenges, requirements of blockchain adoption in the wine industry and possible interventions.

6. CONCLUSIONS

Blockchain is a potentially disruptive technology for innovative product tracking applications in the wine industry. The need to comply with stringent regulations, combat fraud, and the opportunity to strengthen relationships with consumers make the wine industry a particularly relevant scenario for the development of block-

chain-based systems. However, the diffusion of blockchain in the wine industry is hindered by several organizational and managerial complexities. Despite this, most of the literature provides only theoretical contributions, focusing on generic agrifood applications [6,36]. Furthermore, most studies highlight technical and regulatory limitations, partly overlooking managerial issues [53,54]. Finally, several inquiries focus on large-scale applications, involving big companies and global supply chains [32,55]. Thus, only a few studies investigate the role that blockchain technology can play in the wine industry. Among these, some analyse the potential of blockchain tracking systems from a theoretical perspective [40,56] and a minority focus on the analysis of real cases [11,29]. While providing valuable contributions, these investigate isolated success stories, which may lead to somewhat biased conclusions, leaving a gap in the literature. In this study, we aimed to help bridge this gap by providing empirical evidence of the drivers and challenges to the diffusion of blockchain technology in the wine industry. Specifically, we use a multiple case study approach, interviewing the managers of 16 Italian SMEs. Thus, through a rigorous thematic analysis and a three-step coding process, we effectively support and complement the literature and identify the requirements for the development of blockchain-based tracking solutions that meet the needs of wineries.

From a theoretical perspective, this study offers two main contributions. First, it moves the literature one step forward by analysing the problem of blockchain adoption in the wine industry using a multiple-case study approach. This allowed us to perform cross-case analysis and compare multiple sources of evidence, ultimately introducing new relevant elements into the debate. Second, the study offers a novel perspective on the challenges and opportunities of blockchain adoption in the wine industry by avoiding focusing on single success stories and broadening the scope of the study to take into account the perception of companies representative of the current state of the Italian wine industry. This enabled the identification and analysis of the requirements that a modern blockchain-based system must possess to meet the needs of SMEs in the wine industry.

The results suggest that one of the main obstacles to the diffusion of blockchain is the lack of familiarity with the technology. While valuing supply chain accountability, companies show limited awareness of the potential of blockchain to enhance product tracking. This is exacerbated by several factors, including the lack of technological skills, and the over-reliance of wineries on management support and external technology providers. As for technological skills, the companies stress the difficulty of hiring human resources with advanced technological skills, due to high costs and lack of expert professionals in the sector. As regards the other two factors, results show that the processes of technological innovation in SMEs in the Italian wine industry depend significantly on the vision of top management and collaboration with external providers. This can be a strong driver or a severe hindrance. Managers do not always have the foresight to focus companies' efforts on technological innovation, and it is not guaranteed that partnerships with external providers will provide favourable outcomes. Also, the reliance of Italian wineries on external partners could lead to a stagnation of technological skills. Overall, further studies on the topic are necessary to assess whether these results also hold in different scenarios.

Moving beyond the technological aspects, results suggest that blockchain could play a pivotal role in the wine industry, both as a supply chain control mechanism and as a marketing tool. Indeed, stringent standards require the development of modern digital solutions that help companies monitor the supply chain, track products, and comply with regulations. At the same time, companies may be able to leverage innovative tracking systems to develop new ways to interact with consumers. However, further studies are required to test the validity of these findings in the wider context of global wine value chains.

In terms of practical implications, this study provides institutions, policymakers and companies with useful suggestions to assess the opportunities and challenges of blockchain adoption and to guide the development of blockchain solutions that meet the needs of Italian wineries.

First, to encourage the diffusion of blockchain in the wine industry it is necessary to increase companies' familiarity with the technology. To this end, the creation of strategic partnerships between companies, research institutions and technology providers is crucial. Indeed, companies seem interested in supply chain traceability and transparency issues but struggle to assess the benefits provided by blockchain solutions. At the same time, it is necessary to foster the development of wineries' technological skills. At present, Italian companies struggle to find and hire technology specialists who can drive and manage technological innovation. For this reason, governments must fund training programs and support hiring, while universities may contribute by training new professional figures. Regarding technological issues, a key requirement is the ability of technology providers to develop simple-to-use and low-cost blockchain systems. This is essential to overcome the limited invest-

ment capabilities and skill gaps of SMEs.

As for direct actions that firms can take, the results suggest that wineries could benefit from greater technological expertise. Whereas hiring specialists is too costly or impractical, companies could still make an effort to acquire knowledge by collaborating with universities and research centres and attending conferences. Another initiative is to perform a cost-benefit analysis related to the adoption of an advanced product tracking system. Firms should consider how the use of blockchain solutions could affect their business models and marketing activities, playing into global trends in the industry. Indeed, the wine market is experiencing rapid and significant changes, favouring differentiation strategies and requiring companies to enhance their communication efforts. In this, reflecting on the unique features of the products is crucial, as the literature suggests that product tracking is particularly effective in supporting the sales of high-end products and combating counterfeiting and label adulteration phenomena. Finally, results clearly show that companies in the wine industry might be able to leverage product tracking solutions to prove their compliance with regulations and increase supply chain accountability.

Despite the contributions, this paper is not exempt from limitations. First, this study uses a qualitative approach. This is suitable for exploratory empirical investigations and allowed us to identify key themes related to blockchain adoption in the wine industry. Furthermore, we used a rigorous thematic analysis procedure to reduce the subjectivity of the analyses and increase reliability. At the same time, future research could focus on larger-scale quantitative studies to consolidate and test the findings. Second, this study focuses on SMEs. This helps bridge a gap in the literature, which investigated applications of blockchain in the agrifood industry focusing primarily on large-scale applications. However, this reduces the generalizability of the results, and future studies could analyse the effect of firm size on the choice to adopt blockchain technology. Third, this study focuses on the Italian context. This scenario aligns with the scope and objectives of the investigations but reduces the generalizability of the results, which could change depending on geographical, regulatory or social context. In addition to evaluating the influence of such factors, quantitative analyses are needed to test these findings in cross-national investigations. Finally, this study focuses on the wine industry. While representing one of the most interesting cases for the adoption of blockchain technology, this also limits the generalizability of the results. Wine supply chains present unique characteristics that influence the analysis. Future research could expand these findings by extending the investigation to other sectors of the agrifood industry.

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APPENDIX

Table A1. essential information about the companies and the informants.

Company name	Headquarters	Role of the respondent	Interview date
Tralci Hirpini	Southern Italy	Owner	05 – 31 - 2023
Joaquin Wines	Southern Italy	Sales manager	05 – 26 - 2023
Sella delle Spine	Southern Italy	Sales manager	06 – 05 - 2023
Vini Malavasi	Northern Italy	Owner	07 - 13 - 2023
Francesco Maggi	Northern Italy	Owner	07 – 28 - 2023
Company A	Southern Italy	Owner	07 – 10 - 2023
Company B	Southern Italy	Owner	06 – 01 - 2023
Company C	Southern Italy	Owner	06 – 15 - 2023
Company D	Southern Italy	Production manager	06 – 20 - 2023
Company E	Southern Italy	Production manager	06 – 21 - 2023
Company F	Northern Italy	Owner	07 – 06 - 2023
Company G	Northern Italy	Owner	07 – 28 - 2023
Company H	Northern Italy	Production manager	07 – 12 - 2023
Company I	Central Italy	Owner	07 – 10 - 2023
Company L	Central Italy	Owner	06 – 08 - 2023
Company M	Central Italy	Production manager	07 – 04 - 2023