

Article

Blockchain Technology in Wine Chain for Collecting and Addressing Sustainable Performance: An Exploratory Study

Gloria Luzzani ^{1,*}, Erica Grandis ¹ , Marco Frey ² and Ettore Capri ³ 

¹ Department for Sustainable Food Process, Università Cattolica del Sacro Cuore, 29122 Piacenza, Italy; e.grandis.1@gmail.com

² Department of Management, Sant'Anna Scuola Superiore Universitaria di Pisa, 56127 Pisa, Italy; marco.frey@santannapisa.it

³ European Observatory on Sustainable Agriculture (OPERA), Università Cattolica del Sacro Cuore, 29122 Piacenza, Italy; ettore.capri@unicatt.it

* Correspondence: gloria.luzzani@unicatt.it

Abstract: Sustainability standards have not yet been commonly adopted by the whole wine chain, and indicator assessments are not widely spread. A deep understanding of how embedding sustainability into business while controlling costs related to the adoption of sustainability certification standards such as data collection and management practices could allow one to overcome most barriers relevant to sustainability compliance. Blockchain technology (BCT) may answer these needs. In order to verify BCT potential to be used as a sustainability management tool in the wine industry, with a qualitative triple bottom line research approach, this article explores the connections among BCT adoption in agri-food, issues posed by wine sustainability certification, and whether wine companies that already own a wine sustainability certification are prepared to adopt it. Results show that (1) the blockchain allows collecting data and information that are relevant for monitoring and improving sustainability: Soil and water features, climate conditions, treatment with pesticides and fertilizers, production process, traceability, transparency, labor and human rights, quality and safety, waste reduction, authenticity, relationship with stakeholders; (2) wine companies that already own a sustainability certification have little familiarity with blockchain applications (57.1%, n.21) and only 14% of the respondents support their intention to invest in BCT in the coming years; (3) the case study shows improvements in traceability and transparency along the supply chain and an increase in consumers' trust that was reflected in sales growth, and the main costs are linked to complexity in data management.

Keywords: wine; sustainability; certifications; blockchain



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1. Introduction

In recent decades, the increasing competition and pressure from the world market led the food supply chain to many economic, social, and digital transformations. The latter especially has expanded the range of opportunities for the development and growth of companies, offering solutions to enhance the food sector.

The rapid deployment of new wireless communication technologies and the implementation of Internet of Things (IoT) devices have brought several benefits to the agri-food supply chain, such as the optimization of production, costs reduction, greater traceability and control of products, together with better data management.

In the agri-food sector, data management is extremely important, as it is a necessary condition to demonstrate the product characteristics and its quality to the customer while guarantying food safety, traceability, and all the values related to product and organization sustainability [1]. In this context, the collection and disclosure of data become key monitoring and communication tools that allow manufacturers to tell the story of their brands to consumers. The increasing consumers' expectation about companies' capability to create

value across the triple bottom line of sustainability—economic, social, and environmental [2,3]—is pushing the world markets towards better integration of sustainable practices into business. In the last few years, organizations have started to integrate sustainability into organizational regulations [4] and strategies [5]. In this framework, the most relevant entrepreneurial challenge is to align social and environmental issues with economic gain. Many authors have shown that embedding sustainability into business could increase the competitive advantage and foster the innovation process [6,7], but the implementation of sustainable practices is also subjected to many barriers: The lack of awareness, knowledge, and information within the organization [8]; the lack of measurement of benefits [9,10] and increased time and costs [11]; the lack of communication and information among stakeholders [8]; and the lack of evaluation tools [12].

The agricultural sector is striving to implement better sustainable management with increased compliance to sustainable production [3,13]. The need for responsible sustainable production and consumption is also posed by Agenda 2030, which with its #12 Sustainable Development Goal promotes sustainable management and the efficient use of natural resources [14].

Among agri-food production, the wine industry is the only one that has put forward a growth path to better implementation of sustainable practices in the overall production and distribution process, and for this reason, the wine industry has a high number of sustainability programs, certification processes, and sustainability standards [15,16]. These programs differ in type and scope:

- Sustainable certified winegrowing programs (Organic and Integrated production for instance SQNPI program, i.e., [17,18] are meant to reduce environmental pressure due to agriculture (mainly focused on agrochemicals use, soil degradation, and water stress);
- Sustainability assessment programs are meant to plan improvement and mitigate impacts i.e., [19–21].

In most cases, wine sustainability programs are promoted by governments (such as in the case of VIVA Sustainability and Culture [19]) or by wine industry associations (such as Equalitas [22] and Oesterreich Wein [21]) and mostly provide a private label to certify that the wine or wine organization complies with the sustainability standard set by the certification, after verification. The most common certification processes require the company to adhere to the program through a formal agreement and assess well-defined sustainability indicators and/or implement sustainable best practices in wine production [23] in accordance with the program's technical specifications. On the environmental impact side, sustainability standards addressed to the wine industry include the assessment and improvement of resource depletion, soil degradation, water stress, energy use, solid waste (organic and inorganic), greenhouse gasses emissions, land issues, chemical use, and impact on the ecosystem [24,25]. Furthermore, sustainability standards also take into account to what extent a company can create social value, and to contribute to the development of the territory in which they operate as well as the local community. Therefore, they evaluate the companies' ability to protect and promote the local landscape and the cultural and viticulture heritage [26]. Sustainability programs can provide companies with specific tools to assess sustainability (such as the ones developed in the framework of the VIVA Sustainability and Culture program and Austria sustainable). The assessment methods vary depending on the program's scopes and assumptions: Some of them adopt ISO compliant indicators, others have developed their own methodology to assess and certify sustainability.

Despite this, sustainability certifications or standards have not yet been commonly adopted by the whole wine chain, and indicator assessments are not widespread; on the other hand, sustainability management tools that allow the collection of data about vineyard and winery sustainability and compare them among growers have a high degree of adoption [27], suggesting that sustainable development could be reached through the deployment of interactive management tools. Walker et al. [28] identified the most common

barriers to environmental supply chain management: A lack of understanding on how to incorporate green into buying, cost concern hinders, and accounting methods that limit green reporting. A deep understanding of how embedding sustainability into business while controlling costs related to the adoption of sustainability certification standards such as data collection and management practices could allow one to overcome most barriers relevant to sustainability compliance. Blockchain technology (BCT) may answer those needs, as it is a promising method to increase ecosystem development around themes such as transparency, food integrity, and traceability in agri-food chains [29]. Furthermore, BCT has been shown to be promising for better management of global supply chains with reference to transparency, traceability, and security, which are also reflected in product sustainability [30].

The blockchain can support data collection, storage, and consequential data certification across the overall supply chain by adopting different types of distributed ledger technologies [31]. Data management is a crucial aspect and a current challenge for achieving increased sustainability. Indeed, one of the biggest barriers to integrated sustainable management in companies is the lack of a systematized approach to data collection across the overall supply chain and storage. For instance, the assessment of the carbon footprint of one product requires detailed knowledge about procurement, processing practices, and transportation across the product value chain on a cradle-to-grave basis, and this implies a collective effort across the overall supply value chain and therefore a proactive contribution of the diverse value chain actors. Blockchain has shown promising potential in overcoming this issue, by providing a technology able to trace and map the overall value chain with a timesaving, united, safe, and transparent approach [32].

This overall tracking has been shown to be promising in assuring ethical sourcing and the monitoring of environmental sustainability [33], reducing barriers and complexity to the green supply chain [34], and social sustainability [35]. Danese et al. [36] have shown, by means of a case study, BCT implementation can prevent counterfeiting in the wine supply, while Karadimas et al. [37] proposed a use case of TERRA + BCT in the wine system.

In response to a more pressing and attentive demand for products' sustainability, together with the development and growth prospects of Made in Italy wine, there have been three blockchain applications developed, tailored to the wine sector: My StoryTM, Wine Blockchain EY, and EY OpsChain. My StoryTM [38] aims at telling the whole story of the wine bottle: It presents itself as a "generator of trust" because it guarantees the authenticity of the bottles to suppliers, producers, and consumers, making data visible and non-manipulable. The information collected and the results of the verifications of DNV GL constitute the "identity card" of the wine and are accessible by framing a QR-code placed on the wine bottle label. The information includes vine features (i.e., place, soil), production methods, obtained certifications, transformation practices, and bottling phases. The MyStoryTM system is currently adopted by three wineries in Italy [39]. Wine Blockchain EY [40], developed by EY Italia in collaboration with the startup EzLab, has allowed the creation of a public register linked to the digital signature of the producer. The data are immutable and map each step of the supply chain, from vineyard to table, and it certifies the origin of the raw materials, their territoriality, quality, authenticity, and all the phases of the wine chain [41]. Recently, EY also developed an additional blockchain application: EY OpsChain, which was used to create the basis of the TATTOO (Traceability, Authenticity, Transparency, Trade, Origin, and Opinion) Wine e-commerce platform, of Blockchain Wine Pte. Ltd. The latter uses EY's blockchain solution to promote and sell wines all over the world, with a focus on the markets of China, Japan, South Korea, Thailand, and Singapore, where the consumption of European wines is growing rapidly. EY OpsChain also assigns a QR code to each bottle that allows access to information about the producer, vineyard location, field in which the grapes were grown, vines used, pesticide and agricultural treatments carried out, organoleptic characteristics, conditions of transport of the batch for processing into wine and for delivery, and the processing method. To date,

the EY OpsChain traceability module has helped track more than 11 million bottles of wine worldwide [41].

The literature on the environmental, social, and economic impacts of wine production is vast. Scholars have mainly focused on the development and assessment of sustainability indicators tailored to the wine system, but the amount of literature that provides insight to improve data collection and management towards sustainability purposes is scarce.

In most cases, the approaches developed to assess environmental sustainability in wine production focus on the water footprint [42,43], carbon footprint [34,44–47], and agronomic indicators to assess the impact of wine production at the vineyard scale [48] as well as ecological sustainability [49].

Many scholars have adopted these indicators to carry out concrete case studies on the water [50–52] and carbon footprints [51,53–55] of specific wine labels.

Luzzani et al. [56] developed a comprehensive qualitative framework that can assist wine companies in integrating sustainable best practices on territorial management with main references to biodiversity, the community, and the economy.

Merli et al. [57] analyzed current knowledge gaps and the path forward towards the development of an international indicator system, by means of the integration of new indicator sets.

Neither the above-mentioned studies nor the existing literature provide information on how companies should collect and organize data for product sustainability analysis, nor how the collection of the necessary information should be managed across the value chain so as to make sustainability assessment scalable across the entire wine system, as well as decentralizing data collection and management.

Some of the features and uses of BCT appear to have the potential to address sustainability in the supply chain. This study analyzes the criteria of sustainability in the wine system (indicators used and dimensions) and identifies, via a sector-specific approach, the overlaps between the purposes of the use of BCT in the supply chain of the food sector and the characteristics of wine sustainability certifications. Nothing has been done so far to explore whether BCT can be adopted at company and value chain levels to collect and store data, if this technology is acceptable to wine producers, and what the current costs are in order to test if BCT use can be explored further. In order to verify the potential of BCT to be used as a sustainability management tool in the wine industry, the present exploratory study has been developed, aiming at exploring (i) the current use of BCT in agri-food and its overlaps with the requirements of wine sustainability certification, (ii) the level of knowledge and readiness to adopt BCT among wine companies that already own a wine sustainability certification, and (iii) the benefits and costs of BCT adoption in wine companies by means of a case study.

2. Materials and Methods

The present study adopts a mixed-method approach that encompasses a systematic literature review combined with a questionnaire survey and a case study. The study is divided into three phases. Each phase addresses one of the following research questions (RQ) that were put forward to be tested, in consideration of the background conceptual framework.

RQ1—Can a blockchain system applied to the wine chain address specific arguments of wine sustainability certification?

RQ2—To what extent are wine companies that already own a sustainability certification ready to adopt BCT?

RQ3—What are the potential benefits and costs of BCT adoption in the wine industry?

RQ1 has been developed in accordance with the literature that studies the use of the blockchain for addressing sustainability issues such as green supply chain, traceability, and social sustainability, to take a step further and direct focus to a specific value chain.

To test RQ1, a systematic literature review on the main characteristics and objectives of wine sustainability certifications was conducted to identify overlaps between the intended use of BCT and wine sustainability certifications features.

RQ2 aimed at assessing the readiness of adopting technology to verify whether there exist potential barriers to the adoption of a BCT system as a support tool to address sustainability challenges. The present RQ is the logical consequence of RQ1, whereby if a BCT is applicable to wine sustainability certification and therefore can be adapted by wine producers, gaining an understanding of their readiness to adopt is useful to better identify constraints, barriers, and potential drivers.

RQ2 was tested through a closed-ended questionnaire addressed to 40 wine companies that had already implemented VIVA Sustainability and culture certification, while RQ3 was tested through a case study of a wine company that is already adopting BCT to improve production and processing traceability and communication with consumers. RQ3 was conceived with the aim to identify benefits and costs related to the adoption of BCT and collect qualitative information that better describes barriers to BCT adoption.

2.1. Literature Review Methodology

To achieve the research aims and address the key research questions, this study firstly conducted a systematic literature review (SLR) [58] to identify BCT characteristics, current development, and applications and compare them with current solutions for assessing and monitoring sustainability criteria in the wine chain set by wine sustainability programs, certifications, and standards. The research question of this study phase is:

RQ1—Can a blockchain system applied to the wine chain address specific arguments of wine sustainability certification?

In order to test RQ1, the following steps were followed:

- (1) Identification of sustainability criteria that are most common in wine sustainability certifications, programs, and standards;
- (2) Analysis of the correspondence among BCT fields of applications and objectives with sustainability criteria found in I step.

The present study phase employed diverse typologies of materials for data collection, i.e., reports, programs' technical specifications, and scholarly literature.

The inclusion criteria are listed in Table 1.

Table 1. Inclusion criteria.

Inclusion Criteria	Rationale
Technical specification of private and public programs, certifications, or standard for wine sustainability	Technical specifications clarify application, pillars and features of sustainability programs in the wine sector
Peer-reviewed articles about wine sustainability	Useful to identify the most common field of interest and application of sustainability in the wine industry. Peer-reviewed studies have higher scientific relevance
Peer-reviewed articles about BCT application in the agri-food sector	Useful to identify the most common field of application of BCT in agri-food. Peer-reviewed studies have higher scientific relevance.

Three databases were selected for the literature search: Science Direct, Web of Science, and Scopus. Keywords used for the research criteria were “sustainability”, “blockchain”, “wine sustainability”, “wine certification”, “wine sustainability indicators”, “wine sustainability programs”, “wine blockchain”, “agri-food blockchain”, “agriculture blockchain”, and “food blockchain”. Boolean connectors were employed to increase accuracy.

Only contributions in the last 10 years were considered since BCT has developed in the last decade, as did wine sustainability programs that are already applicable. Table 2 shows the full list of query strings.

Table 2. Search strings.

Topic	Search String
Wine sustainability certification	“wine sustainability” OR “wine certification” OR “wine sustainability indicators” OR “wine sustainability programs”
Blockchain current application in the agri-food sector	“sustainability” AND “wine blockchain” OR “agri-food blockchain” OR “agriculture blockchain” OR “food blockchain”

The resulting preliminary sample was further filtered to exclude non-aligned topics, and additional exclusions were carried out to omit duplicates or non-relevant studies that did not meet inclusion criteria expressed in Table 1. Finally, the sustainability criteria found in step I were aligned with and applied to BCT applications in agri-food found in step II.

The present research phase served as the basis to set research phases 2 (RQ2) and 3 (RQ3).

2.2. Survey RQ 2 Methodology

After a literature review, an online questionnaire was designed to explore the level of knowledge and willingness to adopt BCT among wine companies that have already undertaken the first steps on the path towards sustainability, in order to answer the following research question:

RQ2—To what extent are wine companies that already own a sustainability certification ready to adopt BCT?

The study area for RQ2 was the Italian wine industry, which, with a value of 11 billion euros, represents one of the excellences of Made in Italy. In 2019, Italy was confirmed as the world’s leading wine producer for the fourth consecutive year, with 2000 industrial companies and 50.4 million hectoliters produced [33].

The questionnaire was addressed to wine companies that, at the time of the survey, owned a product or organization certification released by the VIVA Sustainability and Culture standard, the publicly recognized certification program for wine and wine companies’ sustainability in Italy. The VIVA Sustainability and Culture program was started by the Italian Ministry for the Environment, Land, and Sea in 2014 and is targeted to the wine industry with the aim to assess and improve the social, economic, and environmental impact of wine production and wine companies [19]. The questionnaire was submitted to 40 VIVA-certified wine companies, which included all the wineries that held a VIVA certification at the time of the survey. Data were collected from 2 October to 2 November 2019, after a pilot test of the questionnaire.

The questionnaire consisted of 21 single, multiple, or short open-ended questions. These last ones were grouped into five theme blocks: (i) Wine companies’ characteristics, (ii) level of knowledge of the BCT, (iii) propension to the implementation of the BCT, (iv) opinion on BCT applied to the wine industry, and (v) opinion on future developments of BCT in the wine industry (the extended version of the questionnaire is available as Supplementary Material).

The survey questions have been designed to allow for qualitative measures of the awareness and the readiness to adopt the BCT as a sustainability support system in order to test companies’ willingness to adopt the technology and current beliefs.

2.3. Survey RQ3 Methodology

A semi-structured qualitative interview was addressed to Winery X (WX), which is one of the first movers in the implementation of Wine Blockchain EY, in order to achieve the research aim and answer the following research question:

RQ3—What are the potential benefits and costs of BCT adoption in the wine industry?

The interview was conducted by telephone on 27 October 2019, it was structured in eight flexible open questions, lasted a duration of 45 min, and was addressed to the WX innovation manager.

WX was chosen as a case study among the four wine companies in Italy that are already applying blockchain-based certification systems because, as the first wine company in the world to implement BCT within its wine supply chain, it has more experience, more extensive evidence, and long-term results on BCT adoption.

The interview focused on the following three main themes and relative goals:

- Firstly, it included a section of questions intended to identify the specific needs that have created a favorable context for the adoption of such technology.
- The second block entailed questions aimed at highlighting the factors that led to the adoption of Wine Blockchain EY, any critical issues encountered during its early implementation phases, and the benefits associated with it. The goal was to understand whether, despite BCT being implemented in company management systems only three years ago, improvements in field and cellar performances are already visible, especially in terms of sustainability, product enhancement, and brand perception of consumers.
- The last part of the interview focused on investigating the potential future uses of BCT in the Italian wine industry. The perceived main limitations to large-scale adoption of the technology and certain forecasts about its diffusion in the near future were also considered. Finally, the focus shifted to any suggestions from the company about how to facilitate the transition to a decentralized system such as BCT by Italian wine companies.

3. Results

3.1. Wine Sustainability Certification and BCT Application

The present section shows the results related to RQ1:

RQ1—Can a blockchain system applied to the wine chain address specific arguments of wine sustainability certification?

The literature review led to a preliminary sample of 532 contributions. After further exclusion of unaligned topics, there were six remaining contributions to wine sustainability and seven to the application of BCT in the agri-food sector.

In Table 3, the most commonly recurring sustainability criteria in wine sustainability programs or certifications are reported. Wine sustainability certifications, programs, and standards include both environmental and socio-economic impacts, with the most common environmental themes being water use, climate impact (also measured as greenhouse gasses emissions), soil management, waste management, energy efficiency, biodiversity, and agrochemical use. On the socio-economic impact side, the prevailing themes were wine quality and safety, stakeholder relations, human resource management, traceability, transparency, communication to consumers, local community improvement, education, enotourism, and cooperativism.

Table 3. Wine sustainability criteria.

	Author	Title	Wine Sustainability Criteria
1	[59]	Ecosystem services for wine sustainability: A case in point of sustainable food systems	Water use efficiency; soil management; carbon emissions; energy; biodiversity; winery waste management.
2	[60]	Wine, sustainability and the territorial genetic identity	Territorial identity
3	[61]	What is sustainability in the wine world? A cross-country analysis of wine sustainability frameworks	Economic sustainability of structures and territories; Quality and safety;

Table 3. Cont.

	Author	Title	Wine Sustainability Criteria
			Heritage, historical, cultural, ecological and aesthetic aspects; Site selection; Biodiversity; Variety selection; Solid waste; Soil management; Energy use; Water management; Neighboring land use; local community improvement; education.
4	[15]	Comparing wine sustainability certifications around the world: history, status and opportunity	Traceability; ethical trading; biodiversity; integrity; water use; climate impact; soil management; improvement of local community; education.
5	[62]	Sustainability in the winemaking industry: An analysis of Southern Brazilian companies based on a literature review	Soil management; Energy use; Cooperativism; Enotourism; Agrochemical use
6	[25]	Critical environmental concerns in wine production: an integrative review	Water-use and quality; Solid waste-organic and inorganic; Energy use; Climate impact; Agrochemical use; Land use issues; Impact on ecosystems

In Table 4, the main applications of the BCT in the agri-food sector are shown.

Table 4. Blockchain application in agri-food sector.

	Reference	Title	Main Blockchain Application
7	[64]	Agri-food 4.0: A survey of the supply chains and technologies for the future agriculture	Traceability; Reduction of wastes due to the enhanced traceability; Transparency (better informed consumers); Quality and Safety; Collaboration
8	[63]	Future challenges on the use of blockchain for food traceability analysis	Traceability; Transparency; Security and Safety; Reduction of climate impact (greenhouse gasses emissions) due to the enhanced traceability; Better informed consumers and therefore better relationship with stakeholders; Digital identity
9	[35]	System architecture for blockchain based transparency of supply chain social sustainability	Traceability; Transparency; Labor and human rights; Workplace health and safety
10	[65]	Applying blockchain technology to improve agri-food traceability: A review of development methods, benefits and challenges	Traceability; Collaboration and trust; Reducing economic loss and product waste; Transparency
11	[66]	Blockchains in operations and supply chains: A model and reference implementation	Quality and safety; Authenticity; Traceability

Table 4. Cont.

	Reference	Title	Main Blockchain Application
12	[67]	Blockchain technology in agri-food value chain management: A synthesis of applications, challenges and future research directions	Traceability; Transparency; Quality and Safety; Sustainable water management;
13	[68]	1 Blockchain's roles in meeting key supplychain management objectives	Quality and Safety; Traceability

BCT is mainly adopted to increase traceability across the supply chain, and this use is reflected in many areas: The intrinsic features of BCT, which include an easier way to collect information and data (i.e., about field and other operational practices), is adaptable to data monitoring with the aim to reduce carbon and water footprints, improve working conditions, guarantee quality and safety, transparency, and improve the relationship with stakeholders and the local community. The implementation of BCT can enable stakeholders to access information on field operations: All harvested crops can be labelled with Radio Frequency Identification (RFID) technology, which can collect environmental information about the production area such as soil characteristics, water management and use, climate conditions, and on-field operations such as the application of fertilizers and pesticides, quality of seeds, working practices (e.g., time spent for biodiversity management, field management, field operations), variety, planting time, plucking time, growing conditions, and the staff involved [63].

By confronting the identified wine sustainability criteria with blockchain applications in the agri-food sector, many correspondences have emerged. Traceability is widely accepted as one of the main blockchain applications [35,63,64,66–68] as well as transparency to stakeholders [35,63–67]. Lezoche et al. [64] reported that traceability could positively affect environmental sustainability by providing information on how to reduce “the use of water and other natural resources” and improve soil quality while reducing wastes thanks to “the use of real-time data for decision making”. Furthermore, data collection and storage, transparency, and decentralization, which are intrinsic features of BCT, can also improve human resources management, by providing more information on labor and human rights across the overall value chain as well as workplace health and safety, which are all aspects that can support increased control and implementation of sustainability.

In the current globalized market, traceability is central to safeguarding food safety and preventing contaminated food from reaching consumers. Consumers' demand for safer food and more sustainable production has increased, as a response to the increased concern for dietary and non-dietary exposure to agrochemicals [69]. Lezoche et al. [64] found that BCT can, through improved traceability, ensure food safety and quality, resulting in positive impacts on customer satisfaction. BCT can meet these needs; Walmart for instance, to address the risk related to food contamination scandals, has adopted blockchain technology for managing pork and mangoes [70]. Similar case studies are reported for grain [71] and rice [72] chains for whom the BCT was shown to increase security, while reducing fraud, disputes, and information asymmetry. Traceability, transparency, and quality are strictly linked to authenticity and origin identification, and in this sense, the BCT is shaping the new concept of “digital identity [63,66]. Some BCT applications are changing the nature of communicating with consumers by supporting and improving the relationship among food companies and their stakeholders, which can also be reflected in social sustainability.

Figure 1 shows how BCT can be integrated in the wine supply chain and the sustainability dimensions that it can address. According to the analysis carried out, BCT can be adopted as a support system to collect, store, and provide information on (i) waste and water management, greenhouse gas emission, and the use of agrochemicals and raw materials and inputs (those aspects can be reconducted to the environmental dimension

of wine sustainability); (ii) product quality and safety (and therefore it assures increased transparency to consumers and other stakeholders), workplace health and safety, labor and human rights, territorial identity and authenticity, and health of the local community (those aspects can be redirected to the social dimension of wine sustainability); and (iii) procurement practices and monitoring of economic loss (economic dimension of wine sustainability). From our analysis, no evidence has emerged on how BCT applications could address aspects that are dependent on the relationship between value chain actors and the community/territory in which they operate that can also be described by qualitative (and not only quantitative) information such as how the winery contributes to the economic sustainability of structures and territories, the impact on neighboring land use of its operations, and how it empowers the local communities (i.e., education, collaboration on the promotion of the territory and its tradition).

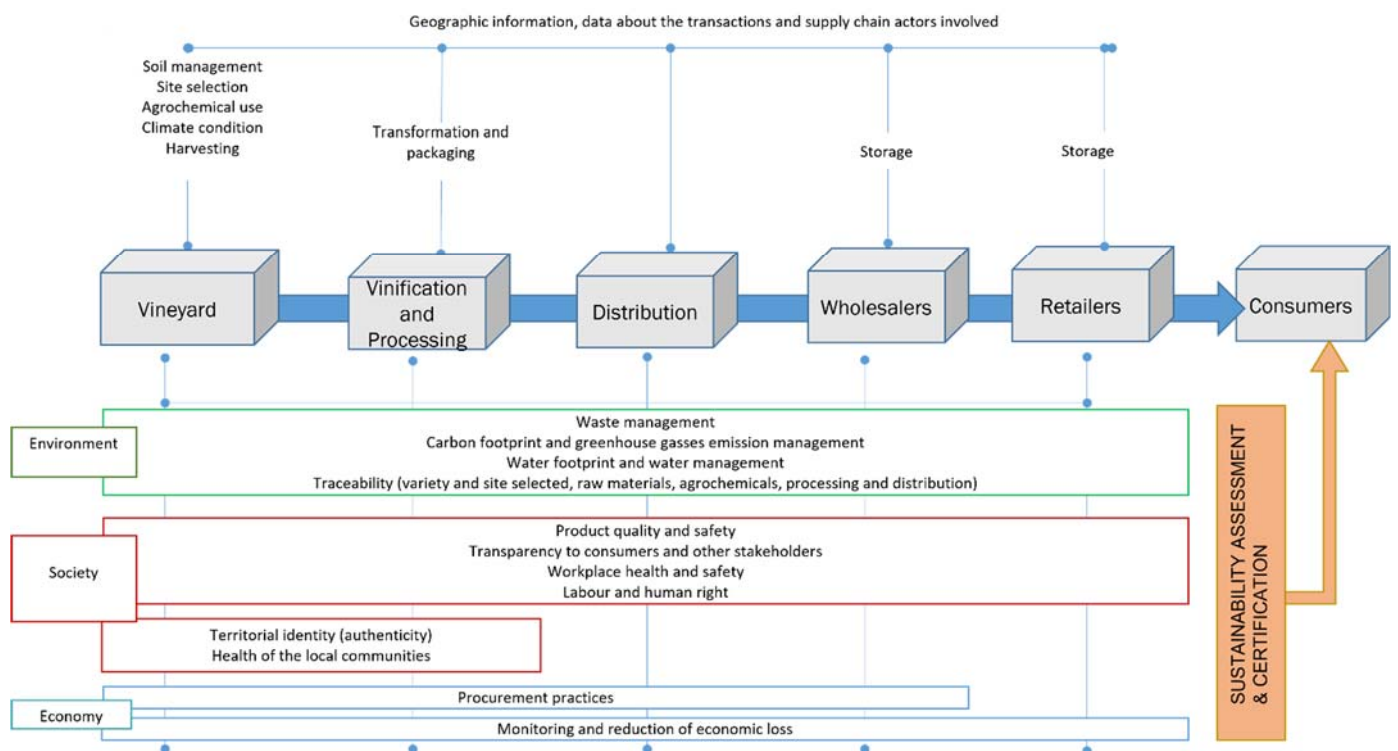


Figure 1. Integration of Blockchain-based wine chain and sustainability criteria in wine system.

3.2. Is BCT Suitable for Wine Sustainability Certification?

The present section shows the results related to:

RQ2—To what extent are wine companies that already own a sustainability certification ready to adopt BCT?

Of the 40 companies contacted, 21 participated in the survey, for a response rate of 52.5%. The wineries are homogeneously spread throughout the Italian territory.

The respondents' profiles are heterogeneous and include small-medium wine companies with a turnover between 1.5 and 2.5 million euros per year, and large groups with sales revenues up to 245 million euros per year. The majority of the respondents (57.1%) have other quality and sustainability certifications in addition to VIVA, a symptom of a deep-rooted interest in environmental and sustainability issues, which apparently requires several means of communication to be effectively transferred to the market.

The majority (57%) of the respondents believe that traditional environmental certification systems work correctly, without the need for modifications or improvements.

Most of the interviewees (57.1%) have little familiarity with the BCT, while the percentage of those who have no idea of its existence is very low. On the other hand, companies that are well informed about BCT are a minority: Only 14.3% declare to have thorough

awareness and preparation on the subject, the same companies that stated their intention to invest in this technology in the coming years.

Regarding the BCT implementation level, there is still a widespread lack of awareness. In fact, 42.9% of the interviewed wine companies are unable to tackle the complexity of such an investment choice, as they do not have sufficient information, and 28.6% of respondents consider the implementation extremely complex and, therefore, not achievable in the short run.

The most frequently noted perceived benefit (47.7%) of BCT adoption is related to increased traceability and transparency along the value chain, followed by simplified data and transaction management (33.3%) and increased competitiveness in foreign markets (23.8%).

Participating companies were asked to give their opinion on the extent to which the use of this technology could influence or strengthen trust between producers and consumers: On a rating scale of 1 to 5, where 1 means “It has absolutely no influence” and 5 “It has a decisive influence”, the largest share (38.1%) is placed at an intermediate level.

Finally, participants were asked what are, in their opinion, the future developments of the blockchain within the wine supply chain. In line with what emerged from the results previously reported, a large part of the sample stated that they were unable to provide predictions. However, an equal percentage (42.9%) is convinced that this innovation will spread through the sector, even if the transition is complex and time-consuming. On the other hand, 9.5% say that the blockchain will have no way to develop further in the wine industry, due to the incompatibility between the latter and such technology initially designed for insurance and finance markets. Only one of the respondents considers blockchain a revolutionary technology perfectly applicable to the wine context.

3.3. Blockchain in Wine Industry: Benefits and Costs

The present section shows the results related to:

RQ3—What are the potential benefits and costs of BCT adoption in the wine industry?

To answer this question, an Italian winery (WX) was interviewed by means of a telephone interview.

WX reports having adopted Wine Blockchain EY with the first aim to certify traceability and guarantee transparency along its supply chain, to meet the needs of an increasingly attentive demand on environmental issues, improve communication with stakeholders, and ensure quality and territoriality of its Falanghina wine, which is the wine that has been certified by the wine BCT EY. Since WX export (with a presence mainly concentrated in Eastern Europe) does not significantly affect its total sales, the main efforts in terms of marketing and investments are addressed in limited foreign markets, while the greatest commitment remains at the national level. Despite this, according to WX, one of the most common phenomena when opting for internationalization is an increased risk of wine counterfeiting, which can be addressed by BCT.

With regard to any difficulties encountered in the phases of ex ante and ex post implementation of BCT, the interviewee declares increased complexity in data management: Poor internal e-skills still represents one of the biggest limits in the adoption of BCT, therefore the willingness to adopt and to invest into this technology are also dependent on the presence of employees with IT skills within the company.

Despite the recent application of Wine Blockchain EY by WX, which dates back to 2017, positive results in terms of performance improvement are already visible: The wine companies recorded a Return On Investment of 15%, which translates into a reduction in both operating and quality assurance costs of 20% and 25%, respectively. Such a result is due to a radical transformation of how data and information are handled, which switched from a paper-based to a fully digitalized system. WX also reports a growth in sales, which they attribute to the increased differentiation of its wine, due to the digital BCT label, which is perceived as a trigger for arousing consumers' curiosity. Consequently, consumers are more engaged and have an increasing desire to experience the BCT-labelled wine so

they can learn more about the history behind it, with a consequent improvement in the relationship between producers and stakeholders. The interviewee also reported better market knowledge, whereby thanks to the use of Google Analytics, WX has easy access to information about the interest attributable to the BCT label, since they are aware of the number of users who have scanned the QR code. These software tools assist the analysis of the demand and are thus able to guide the company's marketing and investment choices.

4. Discussion

The results of the SLR show that BCT use is potentially adaptable to sustainability monitoring and management and that its present use in agri-food is in alignment with the criteria considered by sustainability programs, certifications, and standards targeted to the wine industry. Real-time traceability of a single bottle of wine ensures the safety of a certified product for consumers, resulting in increased trust between the latter and the wine producer. Data can not only serve to increase trust across the food chain but also guarantee transparency to consumers [73], while assuring visibility of wine producers' efforts and investments, providing a direct tool to communicate a product's sustainable value. The benefits provided by BCT adoption, shown by the WX interview and in general by the SLR analysis, entails a greater trust between companies and end-consumers, who can access information related to the "virtual KM-zero product" through a digital label placed on each wine bottle. As reported in Section 3.3, Blockchain EY (the one implemented by WX) allows the collection of data about field features, treatments carried out, and supply chain steps (including the number of "kilometers" travelled), and the sharing of this information among all chains on the net, according to the logic of the distributed ledger. In a such way, wine chain actors and consumers can access information about raw materials and wine products at any time and point of sale. This information is one step before those shared, for instance, by the VIVA-Sustainability and Culture label, which also collects data on field operations (such as agrochemicals treatments, soil management, irrigation) and kilometers travelled by raw materials and products. Similar to the WX wine label, the VIVA label embodies a QR code leading to a digital label, which provides information about sustainability performances: The amount of CO₂eq emitted along the life cycle of the product (including those related to transportation along all the wine supply chain), the amount of water withdrawn from freshwater bodies, water contaminants (measured as the amount of water needed to reduce contamination under the legal limit), and the agronomic impact on soil degradation. The sustainability indicator assessment of VIVA sustainability and culture certification is carried out in online applications that require the same input data collected by BCT: Climate information, vineyards information, soil features, water body features and localization, and pesticides and fertilizers application (time and type). Substantially, the VIVA label provides information about the environmental burdens of raw data that are already elaborated, while the WX BCT label reports the raw data themselves.

More generally, as the SLR results show, data collected via BCT include all steps of wine production and the supply chain and are aligned with input data of the most common sustainability indicators. Input resources withdrawal reduction and efficiency in input use are relevant mitigation practices in sustainable wine production [74] and BCT is a promising way to overcome the barriers posed by data collection in sustainability assessment, which is relevant to monitoring input use and is also one of the main indirect costs of wine sustainability certifications, programs. or standards adoption. Despite this, limited technical expertise and knowledge could also be a significant barrier to the adoption of BCT [30] in the wine industry, as confirmed by WX. Nevertheless, the WX case study also reports the absence of IT skills within the company as a concrete barrier to broader BCT implementation. This aspect should be considered and addressed in parallel to further investigations on the integration of BCT with wine sustainability certifications and programs. Apart from that, the evidence shown by the case study is promising, especially with reference to the impact that BCT has on cost reduction. In a context of ideal full integration between BCT and wine sustainability programs, certifications, or standards, a

proven cost reduction can be helpful in engaging with those companies that are relatively interested in sustainability programs. The questionnaire survey completed by companies certified by the VIVA standard shows that, on the one hand, there is an interest in the theme of BCT as it is believed to boost quality and sustainable production, while on the other hand, results show a serious lack of information and suggest that the market is still immature for a wider application. Wine companies that are particularly interested and informed about BCT are mostly of medium-large dimensions, more structured, or characterized by a more specific division of roles and departments, confirming that companies' dimension and structure play a relevant role when dealing with investments and the adoption of new operative approaches.

The application of BCT in the wine supply chain could have several benefits, including that of enhancing the commitment of winemaking realities in guaranteeing the origin and authenticity of their products. This last one represents a central asset for wineries, which can increase their competitiveness in international markets by focusing on exclusivity and quality.

The greatest benefits of the blockchain concern realities characterized by higher fragmentation and complexity of the supply chain because it provides greater control along the entire value chain, which is common in the wine industry, i.e., the abundance of grape suppliers, many locations for transformation processes, and external subjects for distribution and sale to the public.

However, the widespread presence of small-medium-sized and family-run companies may represent a limit to large-scale investment in BCT, which could be considered out of budget or currently not pursuable due to the existence of other priorities or an unexpressed need. In fact, a greater number of stakeholders and stages of production in the wine supply chain could lead to slowing in the BCT adoption process, since it is necessary to change a large number of data management systems. Another element of difficulty could be represented by the lack of specialized personnel at each stage of production, able to efficiently implement the BCT application.

5. Conclusions

Wine sustainability certifications commonly focus on the assessment and improvement of sustainability at the product and winery levels. As already reported (Introduction 1), the most common indicators used are: (i) the water footprint; (ii) the carbon footprint; (iii) the agronomic footprint; and (iv) the social-territorial impact. The adoption of a blockchain system can assist in sustainability improvements in wine companies. First, BCT increases traceability and transparency in business processes, which results in increased information symmetry throughout the entire production cycle. This results in easier control of sourcing processes, processing, and wine production.

The relatively low time-consuming and effective traceability system offered by BCT can be adopted by wine companies and implemented as a data collection support tool in wine certifications. BCT can support data collection and storage in production, processing, and raw material tracking. This supply chain mapping, completed by reliable and verifiable data, can support the assessment and the reduction of carbon, agronomic, and water footprints that are also at the heart of the wine certifications system. In fact, BCT could be adopted by wine sustainability certifications, programs, or standards as a tool to monitor greenhouse gas emission and water management. The fast and convenient traceability system offered by BCT also shows future promise in detecting unethical suppliers, unfair labor practices, and counterfeit products.

The increased transparency and traceability allowed by BCT along the supply chain results in efficiency in resource management, reduced costs and waste throughout the production process, and potential improvement in sustainability monitoring. So far, it is possible to monitor the environmental, social, and economic impact of wine production with the use of BCT, but further development is needed in order to pair data collection operated by BCT to sustainability assessment and calculation operated by environmental,

social, and economic indicators. In this sense, the full integration of data collected by BCT with the indicators adopted by wine sustainability programs and certifications deliver indicator outcomes and aggregated information, with the advantage of the implementation of a single tool.

From our analysis it has emerged that adopting BCT as a tool to support sustainability implementation and monitoring across the wine value chain may not be enough to address context-specific aspects that are dependent on the relationship between the value chain actors and the community or the territory in which it operates. Indeed, these actors are not directly involved in the economic transaction process on which BCT focuses. Furthermore, BCT can provide limited qualitative information related to the interactions between the wineries and its territory (i.e., education, collaboration on the promotion of the territory, and its tradition).

Further research could focus on identifying technologies and tools that can be paired with BCT to build a complete set of information relevant to sustainability assessment that can include data on landscape valorization and management and improved information on soil and biodiversity management, for instance targeted applications of Artificial Intelligence that have shown promise [75].

There is no evidence on the use of BCT in agri-food to monitor and reduce energy consumption. However, there exists a similar application in other supply chains [76] and this application can be explored further.

The research aimed at considering to what extent BCT could be suitable as a tool to monitor, improve, and certify sustainability in the wine industry. To this end, the present study only surveyed wine companies that had already implemented sustainability certification. The sample choice may be a limitation of the study, since their management could be more sensitive to innovation arguments; further studies should also include wine companies without sustainability certification or with certification other than VIVA. Another limit of the current research can be represented by the boundaries of the study area, which are limited to the Italian wine industry. In fact, the Italian wine industry is mainly characterized by small-medium enterprises and family-run businesses that, by definition, are less prone to innovation implementation due to their company structure.

The present study represents an exploratory study focused on the identification of the theoretical applications of BCT in the wine system, so that it can serve to support wine sustainability certification. The study does not consider the difference between diverse distributed ledger technologies, although it can represent how they can affect data collection and transactions themselves.

Further research should focus on how to maximize BCT benefits in practice by also comparing different Distributed Ledger Technologies. The present work represents an exploratory investigation, and other research activities could provide a better picture of the context in which the BTCT can be applied, such as the supply chain size and type of sustainability certifications. Furthermore, further studies can test the practical implementation of BCT as a sustainability tool in a wine company in order to tailor a BCT model to support sustainability assessment and monitoring, by pairing it with input resource monitoring and making it more user-friendly.

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