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The role of blockchain technology in supply chain relationships: Balancing efficiency and relational dynamics

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ABSTRACT

The increasing adoption of blockchain technology (BCT) is transforming operations and relational dynamics within agri-food supply chains. Despite a growing number of studies, the impact of BCT on supply chain relationships remains underexplored. This research identifies the salient elements of the link between BCT and relationships. It explores these empirically to understand the impact of BCT adoption and implementation on supply chain relationships in the agri-food industry, relying on social exchange theory and focusing on trust, formal information flow mechanisms, and quality of information flows and communication.

This study undertakes a multiple qualitative case study analysis of seven Italian companies involved in the agri-food industry operating in the wine, beer, and dairy sectors who are considered pioneers of BCT adoption. The results indicate a positive impact of BCT on the automation of supply chain contracts and operational efficiency, on one hand, and the increased quality of relationships, on the other. Supply chain coordination is required for BCT to be effective. In highly concentrated sectors, the contractual power exerted by big players is a vital factor, while in more fragmented and dispersed industries the role of persuasion, relationships, and supply chain contracts are key.

Three key insights emerge and are discussed. These concern: (i) the rethinking of the role of trust in supply chain relationships impacted by the adoption of BCT; (ii) the enhancement of information-sharing and flow mechanisms in supply chain relationships through the adoption of BCT; and (iii) the optimization of information flow quality and communication dynamics through the adoption of BCT.

This study contributes to the existing literature by providing novel empirical evidence regarding the impact of BCT on relationships. It further contributes to the existing literature by analyzing the impact of blockchain applications on the upstream and downstream levels of the supply chain from a management perspective and by identifying the beneficial exchanges, norms, and principles that shape interactions when BCT is implemented.

1. Introduction

Deemed a disruptive technology capable of reshaping organizations and supply chain dynamics, blockchain technology (hereafter BCT[1]) has gained considerable attention for its potential to transform transactions and interactions among supply chain stakeholders, as it facilitates the secure exchange of data in a distributed, immutable, and efficient way (Compagnucci et al., 2022; Gligor et al., 2021; Wang et al., 2019). The key features of BCT—decentralization, transparency, and immutability (Atlam et al., 2018; Centobelli et al., 2022)—coupled with its capacity to create smart contracts and foster innovation, have accelerated its adoption; this is particularly the case in pioneering industries, such as financial services and healthcare (Chang et al., 2019; Haleem et al., 2021; Yu et al., 2018).

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[1] Definition of acronyms used throughout the article: blockchain technology (BCT); social exchange theory (SET); Banca Popolare di Puglia e Basilicata (BPPB); protected denomination of origin (PDO); denomination of controlled origin (DCO); controlled and guaranteed designation of origin (CGDO); enterprise resource planning (ERP).

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Recent literature has explored BCT's application in marketing processes (Peres et al., 2023), its influence on supply chain management (Boukis, 2020; Gligor et al., 2021; Treiblmaier, 2018), and the role it plays in business integration and in the interoperation of business processes within smart supply chains (Galvez et al., 2018; Li et al., 2021; Viriyasitavat et al., 2022). The transformative potential of BCT goes beyond its technical features and impacts the dynamics and quality of relationships among stakeholders. Despite this, extant studies have so far devoted limited attention to the critical dimension of the impact of BCT adoption on relationships.

Among the various sectors investigated, the agri-food industry has recently emerged as a promising arena for BCT application (Bigliardi and Filippelli, 2022; Pandey et al., 2022; Rejeb et al., 2020). Its unique industry traits—such as rapid market fluctuations, shifting consumer expectations, dynamic consumption patterns, and complex networks of interdependent actors—underscore the need for effective stakeholder collaboration and process management (Ada et al., 2021; Barile et al., 2024; Cuel and Cangelosi, 2020; De Vries et al., 2023). BCT has been investigated as a solution to various challenges within food supply chains (Nandi et al., 2021), including improving traceability features, providing accurate carbon emissions measures, eliminating counterfeiting, enhancing supply chain visibility, and contributing to sustainable transformations (Casino et al., 2021; Danese et al., 2021; Friedman and Ormiston, 2022; Pakseresht et al., 2023; Rogerson and Parry, 2020).

Despite these advancements, a knowledge gap persists regarding the potential benefits and challenges of BCT adoption in the agri-food industry (Rejeb et al., 2020; Stranieri et al., 2021), particularly concerning its implications for the nature and quality of business relationships within agri-food supply chains and networks (Treiblmaier, 2018). Social exchange theory (SET) offers a valuable perspective for analyzing these interorganizational relationships, as it highlights the role of trust, information-sharing norms, and adherence to principles as critical relational elements (Cropanzano and Mitchell, 2005). The features of BCT—such as transparency, traceability, and immutability—are likely to influence the dynamics of trust formation, reciprocity norms, information exchange mechanisms, and adherence to established principles governing agri-food supply chain relationships.

The adoption of BCT in the agri-food sector can potentially impact both B2B and B2C relationships by mitigating errors in information sharing and communication (Krzyzanowski Guerra and Boys, 2022). Moreover, BCT can address the need for traceability required to fulfill legal requirements and operate in markets (Casino et al., 2021) and meet increasing consumer demands for information about food provenance and characteristics (Krzyzanowski Guerra and Boys, 2022). It has also played a key role in rebuilding consumer trust following well-known food safety-related scandals (i.e., mad cow disease and toxic milk powder, among others) (Zhao et al., 2019).

In light of this, this study seeks to provide an initial contribution to these gaps and an understanding of the potential challenges and benefits associated with the use of BCT in the agri-food industry by analyzing the changing features and nature of relationships following BCT adoption. In particular, this research aims to conduct an exploratory study to identify the salient elements of the link between BCT and relationships and to explore them empirically. Notably, the research addresses the following exploratory research question (RQ):

RQ: What is the effect of BCT on supply chain relationships?

The answer to this question contributes to the literature, which has so far predominantly focused on specific aspects of BCT adoption (i.e., supply chain visibility and traceability, among others). By examining BCT adoption's influence on the dynamics and quality of relationships within the supply network, this study introduces a novel perspective on upstream relationships in supply chains. Furthermore, it examines the benefits, challenges, and opportunities associated with BCT adoption by contextualizing them within the empirical setting of the agri-food industry. This study undertakes multiple explorative case studies in the agri-food industry in Italy and focuses on businesses considered early BCT adopters in the wine, dairy, and beer sectors.

This paper is organized into five main sections, besides the introduction. In Section 2, we present an overview of BCT and its application, with a focus on the agri-food sector and the impact of BCT on relationships. We rely on the key variables of SET operationalized in the context of BCT, with a particular focus on the concepts of trust, beneficial exchange, norms, and principles for information flows. Section 3 details the research methodology adopted in this study. The case studies are presented in Section 4 alongside the empirical results. Section 5 discusses the main results of the empirical analysis, answers the RQ, and provides managerial implications. Finally, Section 6 presents the concluding remarks, theoretical implications, and limitations, together with a discussion of possible avenues for future research.

2. Theoretical framework

2.1. Unveiling the potential of BCT in the agri-food industry

2.1.1. BCT's features and applications

BCT has been described as a promising and disruptive technology able to radically transform how value is extracted and delivered (Compagnucci et al., 2022). BCT is one of the technologies embedded within the Industry 4.0 paradigm (Zhao et al., 2019). It is defined as *"a digital, decentralized and distributed ledger in which transactions are logged and added in chronological order with the goal of creating permanent and tamperproof records"* (Treiblmaier, 2018: 574) and refers *"to a fully distributed system for cryptographically capturing and storing a consistent, immutable, linear event* log *of transactions between networked actors"* (Risius and Spohrer, 2017: 386).

The information recorded in ledgers by this technology regards the nature of the information, along with its quality, quantity, location, and ownership (Saberi et al., 2019). Given these features, BCT facilitates data sharing and enhances transparency, accountability, efficiency, safety, and traceability (Tripoli and Schmidhuber, 2018; Wang et al., 2019), while also protecting data from tampering, deletion, and revision (Iansiti and Lakhani, 2017; Srivastava and Dashora, 2022).

As supply chains become increasingly complex and fragmented, the demand for reliable technologies that ensure data quality and security while facilitating collaboration along the supply chain to counteract data fragmentation intensifies (Casino et al., 2021; Rogerson and Parry, 2020). According to Sheel and Nath (2019), BCT can positively impact supply chains by reducing production lead times and improving the frequency of new product development, thereby allowing the business to better integrate procurement, transport, and the pre- and post-sales service process. Furthermore, BCT fosters enhanced visibility within supply chains, thus reducing the potential for human error and fraud and enabling interorganizational cooperation (Rogerson and Parry, 2020).

Despite the significant benefits associated with BCT adoption (Casino et al., 2021; Fosso Wamba et al., 2020), several implementation challenges have emerged. First, being a digital technology, blockchain requires infrastructures and digitization procedures to ensure the reliability and trustworthiness of data (Feng et al., 2020). Moreover, achieving interoperability with existing systems and other BCT platforms poses technical challenges that require standardization, flexibility, the collaboration of all stakeholders, and integration among different ledger types (i.e., public and private) (Feng et al., 2020). Beyond the technical issues associated with BCT, companies also encounter social and institutional challenges. Social challenges refer to a lack of knowledge and understanding of BCT among stakeholders and consumers, while institutional challenges derive from poorly developed regulatory frameworks and standards governing BCT (Risius and Spohrer, 2017). A further challenge, as pointed out by Sauer et al. (2022), relates to the continuing fading of enthusiasm among enterprises. Indeed, while many companies launched ambitious projects and initiatives geared toward the uptake of BCT, some scaled back or

withdrew these after the pilot phase, and the overly optimistic wave of interest surrounding this technology seems to have slowed. For example, industry giants such as IBM and Maersk have discontinued their BCT-enabled platforms due to the failure to reach commercial viability.

The extant literature has identified specific fields in which BCT can be applied to the marketing process (Antoniadis et al., 2019; Rejeb et al., 2020) and, more specifically, its impact on customer relationships (Ghose, 2018). Such impacts manifest as trust and transparency, privacy protection, digital marketing security, and loyalty programs. In the same vein, Zhao et al. (2019) and Li et al. (2021) have provided an extensive review of the literature aimed at identifying distinctive fields of BCT application and the benefits and challenges associated with the use of BCT-based platforms in the agri-food sector. Among these, they have identified the themes of value chain traceability, applications in information security, and manufacturing settings as smart contracts. At the same time, the features of these technologies—including transparency, end-to-end traceability, and tamper resistance—have been highlighted as being key to enhancing business integration in the agri-food industry and fostering unprecedented visibility at each step of the food supply chain (Li et al., 2021). Indeed, these technologies bring a common technological language to the agri-food value chain and allow access to the story of foods through their labels (Galvez et al., 2018).

2.1.2. Emerging gaps and motivation of the study

While BCT adoption and implementation have been investigated in different fields, two main gaps have emerged in the literature. The first gap points out the lack of a comprehensive level of blockchain exploration (Jain et al., 2021). In fact, previous literature has thus far provided an extensive analysis of the impact of BCT on the downstream supply chain, with a focus on customer relationships (Köhler and Pizzol, 2020), while only a little attention has been devoted to BCT and B2B relationships to date. Adopting a SET lens to fill this gap could provide valuable insights for understanding the dynamics of interactions facilitated by BCT, shedding light on how exchanges within blockchain networks influence and shape relationships among stakeholders.

The second emerging gap relates to a knowledge deficit regarding the potential benefits and challenges associated with the use of BCT in the agri-food supply chain (Feng et al., 2020; Rejeb et al., 2020). The food supply chain is characterized by its multi-actor nature in its main stages (i.e., production, processing, distribution, retailing, and consumption (Caro et al., 2018)). Due to its complex processes, exchanges within the food supply chain often suffer from a lack of transparency, high vulnerability, and prohibitive costs. The existing literature suggests that implementing BCT in the agri-food industry could improve transparency, trustworthiness, and efficiency by removing unnecessary intermediaries while also resulting in fairer pricing throughout the whole value chain (Saurabh and Dey, 2021). At the same time, an effort has been made by previous studies to identify the technological, infrastructure-related, legal, and interoperability-related challenges associated with BCT applications (Feng et al., 2020).

Studies have focused on specific dimensions of BCT adoption, such as supply chain visibility (Rogerson and Parry, 2020), traceability (Casino et al., 2021), and the fight against counterfeiting (Danese et al., 2021), among others. Against this backdrop, the present study is guided by the ambition to investigate BCT adoption on a more comprehensive level by focusing on the upstream level of the supply chain and investigating how relationships are impacted by BCT adoption in the agri-food industry. BCT's improved importance is due to its potential to face multiple challenges and increasing regulatory requirements. Indeed, recent decades have been marked by a series of food-related incidents that have raised concerns about food safety and transparency; these include the 2013 horsemeat scandal, mad cow disease, African swine fever, and olive oil mislabeling, among others. At the same time, stringent regulations demanding supply chain traceability and accountability have been promoted at the European level by the European Union (i.e., the General Food Law Regulation No 178/2002, the laying down of principles and procedures, the setting up of the European Food Safety Authority, and the steps taken to ensure consumers' interests are met and the effective functioning of the market[2]).

2.2. Adding a relational perspective to BCT

The literature on BCT has extensively analyzed its potential and benefits for both consumers and supply chain actors (Saberi et al., 2019; Treiblmaier, 2018). Recent studies have started to focus on specific aspects of the relationships among businesses in supply chains following the adoption and implementation of BCT in the attempt to shed new light on how such technology transforms B2B relationships (Brookbanks and Parry, 2022; Gligor et al., 2021; Schmidt and Wagner, 2019; Treiblmaier, 2018). For example, Brookbanks and Parry (2022) highlighted how trust changes following the implementation of BCT in the wine supply chain, emphasizing its role in trust-building processes through information sharing and data visibility. In a similar vein, Treiblmaier (2018) and Schmidt and Wagner (2019) analyzed the potential implications of BCT for supply chain management. Gligor et al. (2021) investigated how new technologies are shaping B2B relationships and might lead to the emergence of dark side effects. BCT has emerged in recent studies as holding *"the potential to significantly alter the importance of inter-organizational relationships and to enable trusted information flows between hitherto disconnected companies, which in turn poses new challenges for management"* (Treiblmaier, 2018: 553). Moreover, certain BCT mechanisms, features, and elements can potentially transform brand–consumer relationships by enhancing the transparency of data and information, which improves brand reputation and active customer engagement (Boukis, 2020; Ghose, 2018).

Starting from the evidence presented, we rely on SET as a theoretical framework for this study (Homans, 1958), drawing upon its emphasis on relationships as the governance mechanism of exchange and its focus on the explanatory mechanism of relational interdependence, as outlined by Lambe et al. (2001). This theory has been employed in studies analyzing supply chain management-related research questions (Tran et al., 2022; Yang et al., 2023) and in buyer–supplier relationships (Ellis et al., 2023), as well as in BCT-related empirical research (Wang et al., 2022).

SET's basic assumption is that actors enter into and sustain relationships with the expectation that doing so will be rewarding (Blau, 1968); that is, that exchange interactions will yield economic or social outcomes (Lambe et al., 2001). A further central tenet is that of reciprocity and equity in exchange, explained as the fact that *"one party's actions are conditioned on the other's behavior"* (Cropanzano and Mitchell, 2005: 876). Over time, positive economic and social outcomes enhance partners' mutual trust and commitment to maintaining the exchange relationship. Furthermore, *"Positive exchange interactions over time also produce relational exchange norms that govern the exchange partners' interactions"* (Lambe et al., 2001: 6). There are difficulties and costs associated with establishing and maintaining relationships, which arise from the degree of dependence and interdependence among the involved actors and their possibly divergent goals and expectations (Kelley and Thibaut, 1979).

Early research in the B2B field applied SET in empirical studies (Anderson and Narus, 1984; Heide and John, 1988; Wilson, 1995, among others) and proposed some key variables for the analysis of interorganizational relationships (Lambe et al., 2001); these include trust, commitment, and mutually agreed norms for behavior, cooperation, and dependence. When applied to the realm of BCT, SET can be a useful analytical framework, shedding light on crucial aspects of relationships. Therefore, to advance our understanding of the role of BCT in interorganizational relationships in agri-food, we leverage the conceptual lens of SET and contextualize it in the domain of advanced

[2] https://food.ec.europa.eu/horizontal-topics/general-food-law_en.

technology. Indeed, the essential elements of SET might gain new dimensions in the context of BCT, where the inherent attributes of the technology potentially alter both agri-food actors' relationships and the intrinsic concepts of SET.

First, as mentioned above, the underlying assumptions regarding relationships and exchange are those of reciprocity and beneficial exchange. According to SET, trust comprises reliability, integrity, and commitment, while in B2B relationships trust refers to belief in the fulfillment of obligations. Furthermore, SET posits that trust not only guides the exchange behavior of firms seeking to establish long-term relationships (Claycomb and Frankwick, 1997) but that it is the most important variable in relational exchange (Homans, 1958; Wilson, 1995). When looking at B2B relationships in agri-food supply chains, BCT can facilitate stakeholders' engagement in mutually beneficial exchanges by enhancing transparency and traceability, and thus trust, and reducing the risk of fraud. Indeed, BCT can create a secure and transparent ledger that is difficult to tamper with and that can affect trust in established buyer–supplier relationships (Di Mauro et al., 2024). A BCT-based platform can nurture such relationships with reliable and common trusted data, thus supporting the trust-building process between parties, enhancing the established position of trust gained by the parties (Brookbanks and Parry, 2022), and fostering commitment. On the other hand, BCT has been described as a "trustless system" that enforces contractual compliance without the need for personal relationships, as an architecture for "trustless trust" (Werbach, 2019), and as a "trust-free technology" (Wang et al., 2019), suggesting its impact on the establishment of new business relationships (Treiblmaier, 2018).

It is crucial to address the apparent contradiction stemming from the above characterizations of blockchain as a "trustless" technology and its role in enhancing trust in supply chain relationships by recognizing that while BCT can provide a secure and transparent platform for data exchange, its underlying features are insufficient to establish the level of trust that would convince other supply chain actors to join the platform (De Filippi et al., 2020). Indeed, trust in a BCT-enabled system often hinges on already existing levels of trust or relationships during its initial adoption (Jovanovic et al., 2022). Therefore, while BCT can enhance trust incrementally within established relationships, its adoption and acceptance may still depend on initial levels of trust or factors including regulatory compliance, market pressures, or power dynamics.

Second, SET provides valuable insights into the role of relational norms, defined as *"generally accepted guidelines for interactions between exchange participants"* (Lambe et al., 2001: 24), which serve as governing mechanisms for relationships, thereby curtailing the abuse of power and reducing the threat of opportunism. Norms can, on the one hand, replace or reduce reliance on contracts or other legal mechanisms (Thibaut and Kelley, 1959) and foster flexibility in relationships (Macaulay, 1963); on the other hand, they play a key role in constraining or guiding acceptable behaviors or power dynamics in relationships (Blau, 1968; Emerson, 1962). BCT can potentially enhance the implementation of these norms by reducing information asymmetries. Relational norms in the context of BCT can be further operationalized as information-sharing mechanisms; these are essential for supply chain efficiency and for the development of a collaborative environment, as they underpin the effective implementation of BCT. Indeed, the implementation of BCT has a significant impact in terms of data sharing and information transport mechanisms, as it improves tracking mechanisms and guarantees traceability, thereby ensuring data's consistency and non-modifiability while reducing contractual incompleteness (Polim et al., 2017; Schmidt and Wagner, 2019). These formalized information-sharing mechanisms act as catalysts for information management improvements along the entire supply chain (Wan et al., 2020) while also impacting power dynamics through the mitigation of imbalances in terms of information access and the democratization of exchanges among small and larger actors. Here, a key role is played by smart contracts; that is, the *"executable code that runs on the blockchain to facilitate, execute and enforce the terms of an agreement between untrusted parties"* (Alharby and van Moorsel, 2017: 125) whose automated "behavior" ensures predictability in the execution of business processes.

Finally, considerations regarding trust and formal mechanisms for data and information sharing need to be complemented by attention to relationship quality and communication. According to SET, communication and cooperation positively affect relationships and trust (Anderson and Narus, 1990). Through BCT, past actions and historical transaction records remain available, empowering suppliers and buyers to signal their credibility and commitment to quality while also reducing ex-post opportunism (Schmidt and Wagner, 2019). Such characteristics emphasize data and information content, transparency quality, and timeliness, and it is assumed that BCT reduces information asymmetries, thus contributing to the quality of relationships in the trust-building phase (Brookbanks and Parry, 2022). As a consequence, BCT contributes to the overall quality of relationships by facilitating trust-building efforts and fostering a collaborative environment based on shared information and mutual understanding.

Relying on SET-derived underpinning variables and recent studies analyzing BCT, we propose to investigate the impact of BCT with respect to three core components of relationships; that is: (i) trust, (ii) information flow mechanisms, and (iii) information flow quality and communication. The three concepts are operationalized into themes that we aim to explore and that emerge from the analysis of the literature on BCT through the SET lens. First, we rethink the role of trust in supply chain relationships impacted by the adoption of BCT by exploring the effects of BCT on trust dynamics and examining how transparency, traceability, and secure ledgers influence traditional trust-building processes. Second, we investigate the enhancement of information-sharing and flow mechanisms in supply chain relationships through the adoption of BCT. This theme explores how BCT features such as data consistency, immutability, and the automation of smart contracts change the mechanisms of information exchange, leading to a more efficient and transparent flow of data across the agri-food supply chain network. The last theme addresses the optimization of information flow quality and communication dynamics through the adoption of BCT; it investigates if and how communication dynamics and cooperation principles are enhanced by BCT.

Table 1 provides an overview of the theoretical framework adopted in the context of supply chain relationships and takes into account key BCT characteristics.

3. Research methodology

3.1. Research design

This research aims to explore the impact of BCT implementation on relationships in the agri-food industry. Given the exploratory nature of the RQ, the research adopts a qualitative approach (Yin, 2003) based on a multiple case study methodology (Eisenhardt, 1989). The multiple case study approach is deemed suitable to capture the complexity related to the relationship development and change process within fast-changing and challenging scenarios (Halinen and Törnroos, 2005), as the ones impacted by the emergence of Industry 4.0-related technologies. Moreover, this method is suitable for understanding specific mechanisms and dynamics and discovering new facets of a phenomenon that may expand existing theories (De Massis and Kotlar, 2014; Dubois and Gadde, 2014).

Indeed, the potential of BCT is still relatively underexplored by the majority of Italian agri-food companies; therefore, BCT has considerable growth margins in competitive contexts such as Italian agri-food supply chains, which are made up of numerous small family-run businesses. The underlying assumption of this research is that BCT has the potential to influence relationships in different ways, both in formal dimensions such as contracts and information mechanisms, and in relationship quality aspects such as information asymmetries, thus implying a rethinking of trust, information flow mechanisms, and communication.

Table 1
– BCT characteristics, SET principles, and the resulting emerging themes for the analysis of supply chain relationships.

BCT characteristics		SET basic principles		Emerging themes for the analysis of supply chain relationships
Transparency and traceability (Centobelli et al., 2022; Tripoli and Schmidhuber, 2018) Provision of secure and tamperproof ledgers (Iansiti and Lakhani, 2017)	⟷	Reciprocity (Cropanzano and Mitchell, 2005) Beneficial exchange and trust (Claycomb and Frankwick, 1997; Wilson, 1995)	⇨	Rethinking the role of trust in supply chain relationships impacted by the adoption of BCT
Data consistency and immutability (Atlam et al., 2018; Polim et al., 2017) Formalized information-sharing mechanisms (Wan et al., 2020) Smart contracts (Zhao et al., 2019)	⟷	Norms as relational governance mechanisms (Lambe et al., 2001; Thibaut and Kelley, 1959)	⇨	Enhancing information-sharing and flow mechanisms in supply chain relationships through the adoption of BCT
Buyers' and suppliers' credibility and quality signaling (Schmidt and Wagner, 2019) Reduction of information asymmetries and opportunism (Brookbanks and Perry, 2022)	⟷	Communication and cooperation principles (Anderson and Narus, 1990)	⇨	Optimizing information flow quality and communication dynamics through the adoption of BCT

We adopt an abductive research approach for coding information and elaborating results (Dubois and Gadde, 2002; Yin, 2003) to achieve the study's research objectives. This approach allows us to explain and evaluate real-life complex phenomena by moving back and forth between existing theory and the collected data (Dubois and Gadde, 2002). We consider the abductive approach to be a fitting research approach for our study, as BCT's impact on relationships in the agri-food industry is an emerging phenomenon that cannot be analyzed with deductive or inductive approaches. The abductive approach is operationalized through the systematic combining approach for data analysis (Dubois and Gadde, 2002), which is detailed in Section 3.3.

3.1.1. *Description of selected case studies*

Our case selection followed a purposive sampling strategy (Patton, 2002) aimed at identifying information-rich cases that could provide in-depth insights into the impact of BCT implementation on relationships. The sampling process followed several steps and was based on different criteria. We first focused on the Italian agri-food industry, due to its economic significance and the presence of early BCT adopters. Using industry reports, BCT providers' websites, and the authors' knowledge and expertise, we identified companies considered pioneers in BCT adoption. To capture a range of experiences and explore how BCT implementation and its impact on relationships might vary across different organizational contexts, we deliberately selected companies from different sectors within the agri-food industry, namely those of different sizes, to explore whether and how organizational scale might influence BCT adoption, and those occupying different positions in the supply chain. Beyond agri-food companies, we included other key stakeholders (i.e., banks and IT providers) involved in BCT implementation. The final sample consists of seven Italian companies: five in the wine industry (i.e., Cantine Paololeo, Cantine Torrevento, Casa Girelli, Ricci Curbastro, and Placido Volpone), one in the beer industry (Birra Peroni), and one in the dairy sector (Spinosa).

Cantine Paololeo is a family-owned winery established over 30 years ago, in 1989. The company records a turnover of 23 million euros and serves both national and international clients. The company's vision is based on values such as quality, sustainability, local commitment, integrity, and transparency. Paololeo implemented BCT with a local bank for its Negroamaro Orfeo 2018, one of its most renowned and iconic labels.

Cantine Torrevento is a winery owned by the Liantonio family for more than 70 years (since 1950), with a production philosophy based on sustainability, research, and quality. The winery has adopted the new BCT called MyStory, making it one of the first companies in Italy to use BCT. Torrevento has certified its Veritas Castel del Monte Black Bombino Rosè CGDO 2018.

Casa Girelli has been an Italian family-run winemaking company since 1966. The company promotes the combination of tradition and advanced technologies to achieve quality. Casa Girelli has implemented BCT for its label Nero d'Avola La Mura BIO 2017. It is the first Italian BIO wine for which, thanks to BCT, it was possible to certify the production process, quality, provenance, and supply chain, thereby enhancing the value of quality agri-food. The company implemented the BCT project thanks to a partnership established with EzLab, a technology provider, in collaboration with Ernst & Young, a BCT consulting firm.

The Ricci Curbastro winery is a family-run business founded in 1875 and founded on the core values of tradition, innovation, and sustainability. In 2020, the company started an experimental project for BCT implementation using the MyStory technology for its label I Santella del Gröm Curtefranca Rosso DCO 2013.

Placido Volpone, a winery born from the partnership between Volpone's winemaker family and the well-known actor Michele Placido, relies on the value of its bond with the local area and its experience. The two partners are linked by a friendship rooted in their youth, the strength of which is represented by this business project. The Placido Volpone Winery has certified the supply chain of its Falanghina wine on BCT through a project in collaboration with Ernst & Young and EzLab; this was used to certify their Virtual Km0 wine.

Birra Peroni is one of the best-known Italian brewing companies, founded by Francesco Peroni in 1846. The company is currently owned by the Asahi Group business group and operates three production plants and one malthouse across the Italian landscape. In 2020, the company launched an experimental blockchain traceability project with Ernst & Young's OpsChain involving corn, the signature ingredient of Nastro Azzurro, and the tracking of their 100% Italian malt.

Spinosa is a family-run producer of protected denomination of origin (PDO) Campana Buffalo Mozzarella and Buffalo Ricotta, founded in 1994. Spinosa describes itself as an ambassador for dairy culture and the tradition of the "mozzarella di bufala campana" in Italy and around the world. The company, using Ernst & Young's OpsChain Food Traceability solution, has certified each supply chain phase of its Mozzarella di Bufala Campana POD.

3.2. *Data collection*

Our data collection is based on primary and secondary sources of data. The primary source of data is one-to-one semi-structured interviews (Kvale and Brinkmann, 2009), which allows for the building of knowledge through the exchange of views within a conversation on our underexplored theme. To guide the direction of the topics discussed, we drew common themes from the literature and derived questions to ask the interviewees. For reliability and validity purposes, we developed a flexible research protocol that allowed us to ask the same questions to all the interviewees which at the same time enabled us to vary the degree of detail as well as the focus. The themes addressed in the interviews are related to the impact of BCT adoption on the supply chain, with a focus on relationships. Questions covered the changes in terms of trust,

maturity, knowledge sharing, cooperation, and power; we also investigated these issues from a "formal" point of view by investigating aspects related to smart contracts and data analytics and the implications of the blockchain for the nature and quality of business relationships.

In total, we conducted 13 semi-structured interviews from June 2022 to April 2024. Initially, one interview was conducted with each selected company and actor. Upon reviewing the data, we conducted a second round of interviews with some selected respondents. This decision was based on our analysis of the initial interview transcripts; this analysis identified potential areas in which we could seek additional data and information to fully capture the companies' strategies and practices. By engaging again in interactions with them, we were able to ensure the accurate interpretation of data, thereby validating the information collected in the first interview, and the robustness of our data. Conversely, other companies did not require additional interviews, as the data collected in the first round was sufficiently comprehensive. Secondary data sources were used to achieve the objectives of the research; these included the use of the businesses' websites, industry-specific magazines, press releases, and corporate reports as secondary sources. Table 2 provides information about the semi-structured interviews.

3.3. Data analysis

We employed a two-step analysis, starting with a within-case analysis followed by a cross-case one (Lindgreen et al., 2021). The within-case analysis was accomplished via the detailed coding of individual cases, while the cross-case analysis aimed to identify similarities and differences in key dimensions across cases.

The coding process, conducted manually by the authors, began with the verbatim transcription of the interviews and consultation of secondary data. We first conducted open coding, searching for descriptive information on how companies approached BCT in terms of motivations, involved actors, and outcomes. We created labels using short sentences while preserving the lexicon adopted by the interviewees as much as possible. For example, from the interview with Spinosa, we extracted motivation-related labels such as "to face the phenomenon of counterfeiting and Italian Sounding" and "supply chain data are already collected and communicated to ministries, it is worth making them visible to the end-customer as well." These initial codes were then compared with existing literature and associated with literature-derived categories such as "Operations - Counterfeiting" and "Strategy - Trust building with end-customer," respectively.

To explore the impact of BCT implementation on relationships in the agri-food industry, we reorganized each interview transcript, aligning each quotation with the specific emerging themes presented in Section 2 and summarized in Table 1; that is: (i) rethinking the role of trust in supply chain relationships impacted by the adoption of BCT; (ii) enhancing information-sharing and flow mechanisms in supply chain relationships through the adoption of BCT; and (iii) optimizing information flow quality and communication dynamics through the adoption of BCT. Fig. 1 details the coding process.

As outlined in Section 3.1., this study follows an abductive approach operationalized through systematic combining (Dubois and Gadde, 2002) to highlight the interplay between the research object, methodology, and theory. Following Dubois and Gadde's (2014: 1279) recommendations, we adopted a "tight and emerging" analytical logic, which allowed for a flexible yet structured approach to data analysis. Our analytical process followed a cyclical pattern. We first relied on the literature to derive theory-driven codes to be applied in our empirical setting; this led to the identification of emerging patterns in the empirical data. It was by comparing these patterns with existing literature that we refined the framework and decided to rely on additional concepts due to unanticipated empirical findings as well as the additional theoretical insights gained throughout the process, both of which were finally used to re-examine the data. This iterative process exemplifies the abductive nature of our approach. For example, when unexpected findings emerged from the data, we returned to the literature to

Table 2
– Company and interview information.

Company	Industry	Product linked to BCT	Part of the supply chain covered by BCT[a]	Interviewee	Date and duration
Banca Popolare di Puglia e Basilicata (BPPB)/EZ Lab	Bank/BCT provider	/	/	Marketing Manager/ CEO	June 2022–75 min
Paololeo	Wine	Negroamaro Orfeo 2018	Whole supply chain	CEO/owner	June 2022–45 min
				Marketing Manager	August 2022–30 min
Torrevento	Wine	Veritas Castel del Monte Black Bombino Rosè CGDO 2018	Whole supply chain	CEO/owner	September 2022–45 min
Ricci Curbastro	Wine	i Santella del Gröm Curtefranca Rosso DCO 2013	Whole supply chain	CEO/owner	December 2022–45 min
Placido Volpone	Wine	Virtual Km0 Falanghina	Whole supply chain (except distribution)	IT Specialist	January 2023–45 min April 2024–45 min
Casa Girelli	Wine	Nero d'Avola La Mura BIO 2017	Whole supply chain	Marketing Manager	January 2023–45 min
Spinosa	Dairy	Mozzarella di Bufala Campana POD	Whole supply chain (except animal farming and distribution)	Marketing Manager	January 2023–50 min April 2024–75 min
Birra Peroni/Ernst & Young	Beer/ Consultancy	Nastro Azzurro	Whole supply chain	IT Consultant	January 2023–50 min April 2024–60 min
Ernst & Young	Consultancy	/	/	Consultant for the Spinosa BCT project	April 2024–40 min

[a] The term "whole supply chain" used to describe the part(s) of the supply chain covered by BCT refers to the end-to-end process, from raw material sourcing to final distribution. Specifically, it encompasses raw material sourcing (that is, milk procurement for mozzarella cheese, grain or hops sourcing for beer, and grape harvesting for wine), processing (cheese-making processes for mozzarella cheese, brewing operations for beer, and vinification for wine), storage, transportation and logistics, and distribution.

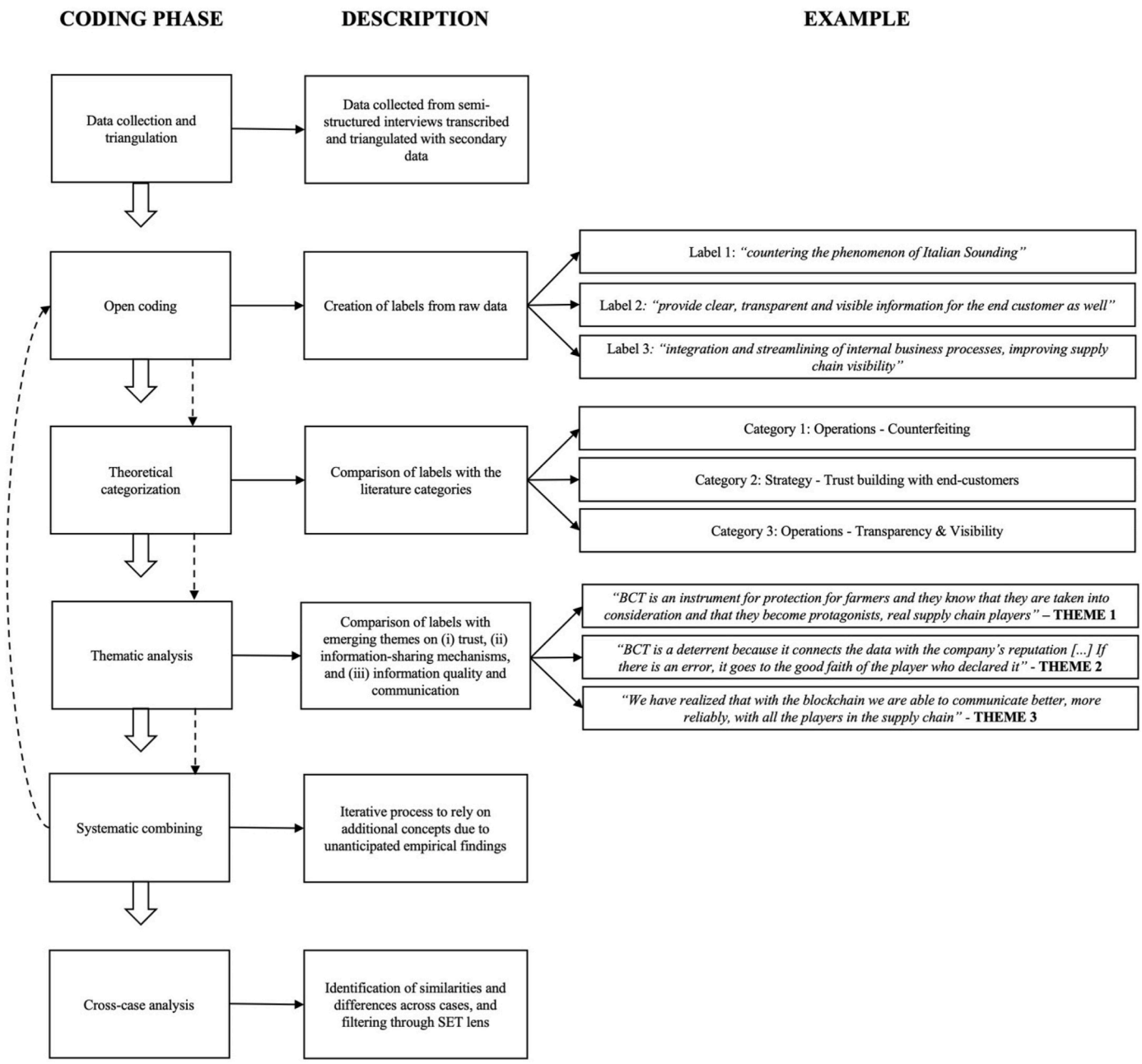

Fig. 1. – The coding process.

seek explanations or to refine our framework; this led in turn to the identification of new theoretical concepts that better explained our empirical observations.

To minimize respondent bias and thus ensure the validity and reliability of the study, we carried out a triangulation of data from primary sources with the data collected from secondary ones. Triangulating data from different sources allows researchers to ensure validity and integrity, thus supporting the qualitative research strategy (Jick, 1979; Patton, 1999), on the one hand, while enabling them to gain a deeper understanding of the studied phenomenon and to track BCT adoption processes, key facts, and main results, on the other. To this end, the interviews were triangulated with data collected from the websites of the companies. We focused on the "news" section, where BCT projects are advertised, and the "production" section, where the specific products for which BCT has been implemented are presented along with their characteristics. We also collected data from the websites of the technology providers, where blogs and portfolios are hosted presenting information on the BCT projects, their underlying motivations, and key results. In the case of well-known companies and BCT projects, specialized local and national magazines were retrieved for consultation.

Our overall theoretical framework for analyzing the impact of BCT on supply chain relationships through the three constructs derived from SET is captured in Fig. 2. The figure summarizes the theoretical framework, as described in Section 2, together with the emerging themes for analysis. The lower level of the figure presents the standard phases of agri-food supply chains and the ledger composing the BCT throughout the supply chain.

4. Empirical results

This section presents empirical data resulting from the multiple case studies conducted. First, we present the results in a descriptive way to introduce the companies and how they approach BCT in terms of

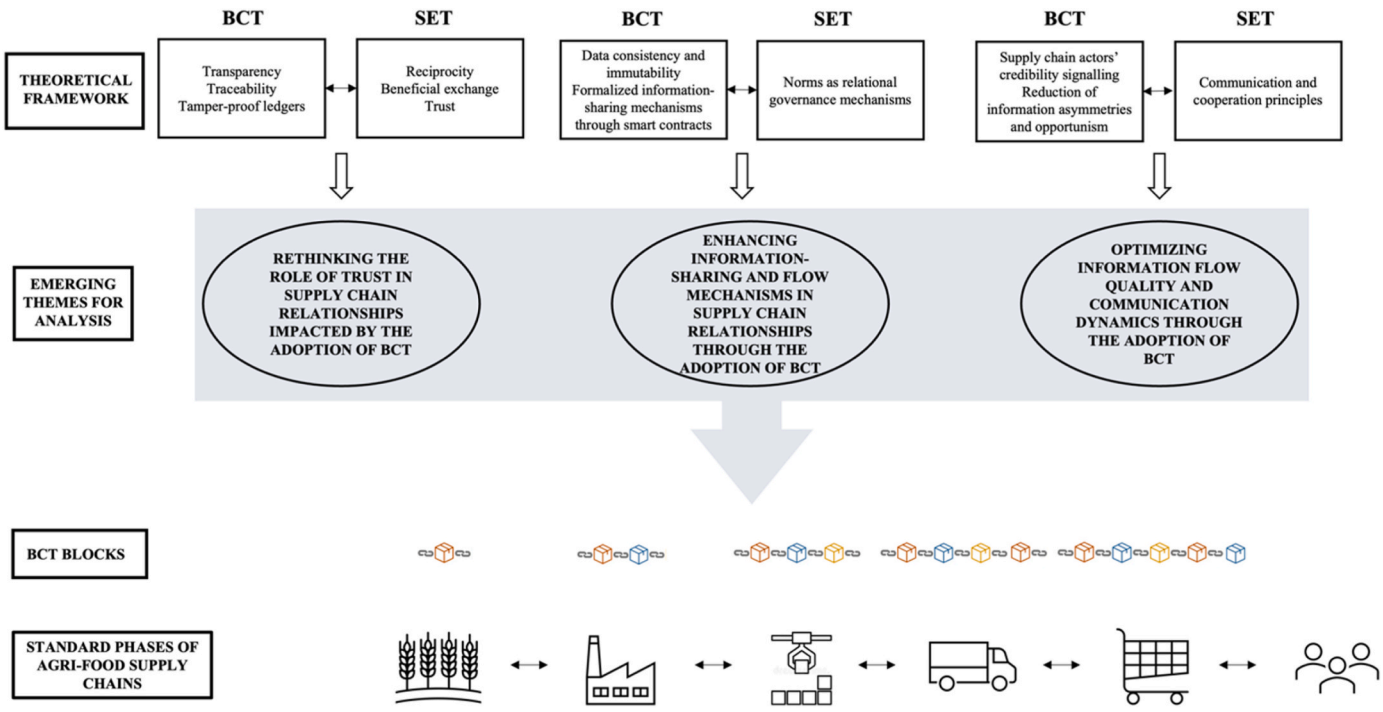

Fig. 2. – Framework for data analysis.

motivations, partners involved, outcomes, and the current status of the implementation, thereby providing an overview of BCT adoption in the Italian agri-food sector. Second, we present the empirical results in line with the themes identified in the literature in Section 2, with a focus on trust, the formal mechanisms for information flows, and the quality of the relationships and communication.

4.1. Implementing BCT in the agri-food sector: Insights from seven Italian cases

The seven selected case studies from the Italian agri-food industry are companies considered early adopters of BCT. The differences characterizing the sample are reflected in the motivations that have driven their choice to adopt such solutions, in the way the companies have chosen to approach the technology, and, finally, in the outcomes and status of the projects the companies have undertaken. Table 3 summarizes the main insights related to BCT adoption in the selected cases.

4.1.1. Motivations for BCT adoption

Concerning motivations, the main reason for BCT adoption, according to the companies analyzed, is not to be found in the possibility of traceability. Indeed, Italian food products are already traced to a high level. Motivations for BCT adoption can be categorized as operational, managerial, strategic, and infrastructure-related (Fosso Wamba et al., 2020); the motivations for BCT adoption identified in the case studies cover the two categories of operational motivations and strategic

Table 3
– Insights into BCT adoption in the selected cases.

Company	Motivations to adopt BCT	Approach to BCT	Outcomes
Paololeo	● Strategy - Trust building with end-customers ● Operations - Transparency & visibility	Pilot BCT project in cooperation with a local bank	● Increased traceability ● Sustainability certification
Torrevento	● Operations - Transparency & visibility ● Strategy - Trust building with end-customers	Adoption of the blockchain-powered digital assurance solution MyStory, developed by the consultancy DNV	● Brand reputation ● Little interest in BCT from supply chain actors ● Lack of commercial returns
Ricci Curbastro	● Strategy - Sustainability ● Strategy - Trust building with end-customers	Adoption of the blockchain-powered digital assurance solution MyStory, developed by the consultancy DNV	● Short-term project ● Modest results from customers
Placido Volpone	● Strategy - Trust building with end-customers	"Wine Blockchain" project in collaboration with the consultancy Ernst & Young and EzLab	● Brand reputation (14% increase in return on investments) ● New product development ● Supply chain performance improvements ● Improvements in supply chain processes
Casa Girelli	● Strategy - Sustainability	Project in collaboration with the consultancy Ernst & Young	● Sales increase ● No cost reduction
Spinosa	● Operations - Counterfeiting ● Strategy - Trust building with end-customers	Adoption of OpsChain Traceability solution developed by Ernst & Young	● Little interest in BCT from supply chain actors ● Increased digitalization of operations
Birra Peroni	● Operations - Transparency & visibility	Adoption of OpsChain Traceability solution developed by Ernst & Young	● Increased engagement with customers ● Productivity and efficiency improvements ● New product development

motivations. From an operational perspective, the motives that prompt businesses to adopt BCT concern fraud reduction (Operations - Counterfeiting) and increased transparency (Operations - Transparency & Visibility). According to the CEO of Torrevento, BCT is also a useful tool in the fight against counterfeiting. In a similar vein, the company Spinosa, which is active in the dairy sector, confirmed the role of BCT in *"countering the phenomenon of Italian Sounding, in the sense of counterfeiting. […] It's not only us companies that are victims of this phenomenon, [and] the restaurateurs abroad, but also small retailers abroad that have Made in Italy products are victims of such counterfeiting"* (Marketing Manager - Spinosa). Other than this, a main identified driver of BCT adoption lies in the fact that the companies already collect supply chain information daily and communicate such information to the ministries and authorities. Therefore, this regulatory pressure pushed them to adopt BCT and turn the information into *"clear, transparent and visible information for the end-customer as well"* (Marketing Manager - Spinosa). A final insight into the operational reasons for adopting and implementing BCT concerns the *"integration and streamlining of internal business processes, improving supply chain visibility"* (IT Consultant - Birra Peroni).

From a strategic point of view, the companies' motivations are related to sustainability issues (Strategy - Sustainability) and customer trust (Strategy - Trust building with end-customers). According to Casa Girelli, the willingness to *"give voice to the strong concept that is at the heart of our mission, that is sustainability, through certifications […] and ensure quality and continuity of supply in the relationships with supply chain actors"* (Marketing Manager - Casa Girelli) represents a strong motivation for BCT adoption. This solution was integrated with analytics and post-sales monitoring by scanning QR codes applied to each bottle. Finally, the novelty prompting the adoption of BCT lies in the fact that the data coming from BCT can be communicated to the final consumer because such data are recorded, certified, and unmodifiable. Therefore, the application of BCT can be used as a powerful tool to *"reach the final consumer and communicate the traceability of our wine"* (CEO/owner - Torrevento). Furthermore, Cantine Paololeo, another company in the wine sector, was driven by the conviction that the value of wine is endowed not only by its organoleptic characteristics but also, above all, by what can be communicated about the wine itself and its origins. What increasingly attracts the consumer is learning about the wine, the path the producer follows, and the cultural and environmental context in which this path is followed.

4.1.2. Adoption and implementation of BCT

The adoption and implementation of BCT has taken different paths in the case studies under analysis. The main ways in which the technology has been embedded in operational processes are through projects and partnerships with local actors (i.e., banks) or autonomously with the support of technology providers and business consultancies. Cantine Paololeo, for example, has started a pilot blockchain project in cooperation with a local bank, BPPB, to guarantee the traceability of the wine's production. Placido Volpone and Casa Girelli have also started their own projects—via collaboration with the consultancy Ernst & Young, in the case of Placido Volpone. The "Wine Blockchain" project was implemented by Gerardo Volpone, son of the owner and Global Blockchain and Innovation Manager at Ernst & Young. Peroni and Spinosa have used the OpsChain Traceability solution developed by Ernst & Young to integrate and streamline internal business processes, thereby improving supply chain visibility. Ricci Curbastro and Torrevento have been guided by the consultancy DNV through their blockchain-powered digital assurance solution, MyStory.

4.1.3. Outcomes and current implementation stage

Looking at the outcomes and current implementation stage after the adoption phase, the companies exhibit different attitudes toward BCT and have contrasting expectations and plans. It is possible to identify shared attitudes and opinions regarding the outcomes resulting from the adoption of BCT in relation to supply chain improvements and brand reputation. For example, Placido Volpone has seen a return in terms of brand reputation, thus building consumer loyalty, and the company has managed to improve its supply chain performance measurement by enhancing internal supply chain processes. Similarly, for Cantine Torrevento, the main result of the process was an improved brand reputation that stemmed from it being among the first three companies to have implemented the technology. However, at the same time, it has experienced a few problems. First, this technology still has limited consumer appeal, with only a few consumers being curious about the information contained in the QR code on the label. Intensified communication and the promotion of the benefits of the technology will be required if the company is to engage the final consumer in these new directions. As a result, there is currently no commercial return in terms of new markets. Second, distributors are busy introducing new products and companies and are, therefore, not interested in this kind of technology. As a result, the competitive advantages of implementing BCT remain limited thus far.

A second outcome concerns new product development. The digitalization of information through BCT allowed Spinosa to make projections and construct hypotheses regarding their strategic choices. For example, they realized that they could reduce the quantity of plastics used for packaging. In a similar vein, according to the IT specialist from Placido Volpone, *"BCT was of interest a few years ago, while in the past few years, the interest has diminished"* and *"BCT does not help in the reduction of production lead times, but it can rather help in the development of new products."*

The remaining opinions of the interviewees range between different types of possible outcomes. Positive ones relate to increased traceability, obtaining sustainability certifications, sales increase, improved digitization of operations, higher engagement with customers, as well as positive results in terms of productivity and efficiency. Negative outcomes include the lack of commercial returns, the short-term nature of BCT projects, modest results from customers, and absence of cost reduction.

There appears to be a difference in companies' mindsets regarding the implementation of BCT. There are those that believe in the potential of BCT—such as Spinosa, which is investing in a new plant based on the interconnections among Industry 4.0 technologies and is using the data coming from BCT implementation as inputs for the realization of new products—and those that view BCT as a limited one-time experience which does not have potential in the context in which it has been implemented. This is the case for Ricci Curbastro as, according to the CEO and owner, the experiment was not very successful, except for a few bottles sold in Croatia and the Netherlands, where customers are particularly interested in blockchain. Overall, although the effort expended in the project was reasonable, the feedback from the end consumer was modest compared to expectations.

4.2. Cross-case patterns: The impact of BCT on relationships

4.2.1. The role of trust

BCT implementation has significant implications for trust within the supply chain and for customer–supplier interaction. First, according to the companies interviewed, the digital immutability of BCT reduces the propensity for fraudulent phenomena, thereby strengthening trust and the relationship. The inability to tamper with what it is communicated externally encourages all the players in the supply chain to work in a more transparent way and maximizes trust among partners. This is because processes become demonstrable, and each actor involved can easily be proved to have contributed with respect to the creation of an information asset. This can lead to beneficial exchanges between all supply chain actors because transparency ensures a greater and fairer distribution of value among supply chain actors and entails greater marginality. From the answers of the interviewees, it emerged that BCT further results in greater trust among the players in the supply chain

because *"many companies have halved the times [spent engaging] in quality control activities, which were previously very expensive [and] required many reconciliations, because in this way they were able to collect information well at the source, correct from the source"* (IT consultant - Birra Peroni/Ernst & Young).

Second, BCT has a direct impact on relationships both downstream and upstream of the supply chain. Downstream, it positions actors as reliable partners for wholesalers and retailers, especially in light of the increasing value of Italian Sounding abroad. Italian supermarkets and restaurants in Eastern countries and in the United Arab Emirates commercialize Italian-certified products, and BCT plays a strategic role in products being chosen over other those of other suppliers because of the immutable digital mechanism that demonstrates reliability. This insight reveals that beneficial exchanges emerge between actors; this is because wholesalers and retailers are able, thanks to BCT, to sell authentic Italian products at a premium price while the producer is able to acquire new foreign customers.

Upstream, BCT enhances credibility and trust because it represents an *"instrument for protection for farmers and they know that they are taken into consideration and that [they] become protagonists, real supply chain players, a role that with other plants they do not have"* (Marketing Manager - Spinosa). The increased credibility and trust acquired thanks to BCT paved the way for the creation of a new supply chain contract for Spinosa, thus indicating that the use of BCT can generate mutually beneficial exchanges. Buyers strengthen their position in the network by reinforcing the exclusive relationship stipulated in the supply chain contract, while suppliers enjoy contractual security which guarantees them greater stability in revenue flows and recognizes them as integral players within the supply chain and as preferred suppliers.

Initial skepticism and distrust toward BCT, especially in less digitized sectors such as dairy, was overcome as milk-supplying farmers became familiar with the digital tools necessary for operating BCT and began to appreciate two great advantages offered by the technology: time savings and error reduction. These aspects positively influenced the supplier–customer relationship, thus reinforcing mutual trust. Spinosa's experience provides a great example, as the company convinced 49 different suppliers to join the BCT project by leveraging their supply chain relationships. Despite a turnover of 20 million Euros, which designates Spinosa as the strongest player in the supply chain, the company must be very careful in managing its relationships with the farmers who supply buffalo milk, which is much sought-after by their competitors. For example, Spinosa had to convince them to change the method used to communicate the lot, switching from a paper sheet shown on the truck to scanning a QR code to declare the quantity of milk, its origin, and compliance with Spinosa's production specification. In this case, the blockchain has brought about benefits in terms of time and discretion.

On another note, the interviews point to the crucial role played by supply chain relationships and existing trust in BCT's success. Indeed, existing trust serves as a factor that convinces suppliers and other supply chain actors to embrace the digitization initiatives needed to effectively implement BCT, thus counteracting their potential resistance and concerns. In the words of the IT consultant at Birra Peroni, BCT requires the digitization of the entire ecosystem, not only of the individual firm, and:

> *companies must somehow convince their suppliers and their stakeholders of the need to activate a digitization process which, by definition, may not be well received because it represents an increase in work for the same earning[s]. Therefore, in terms of business relationships, it is very important to define clearly the contracts between the parties and to regulate the flows that exist in the relations between the parties; in fact, some companies provide a premium price for better control of the supply chain. It requires intense coordination and an agreement about the BCT use between all supply chain actors. The advantages deriving from transparency must be perceived not only as less effort in controlling the activity of the other players in the supply chain but also as a guarantee of greater overall quality in the development of the supply chain. The product positioning can improve, [and] therefore also the profit margin and the reputation of the brand. In markets with very narrow margins, the shared use of the BCT can support the repositioning of brands and increase the remuneration of the various stakeholders throughout the supply chain.*

Power dynamics are also at stake in BCT adoption, according to the IT specialist at Placido Volpone, a former Ernst & Young global manager for the blockchain project. For example, Carrefour, as a dominant retailer, was in a strong position in relation to the Fileni company, a national player in the poultry meat industry; therefore, it was easy for Carrefour to convince Fileni to adopt the blockchain for its meat. However, Fileni did not possess the same power over its suppliers; that is, the 30 farmers providing information to feed the BCT system. To encourage their participation, Fileni gave its suppliers visibility on the Carrefour landing page. Thus, two alternatives emerge from the interview; either to bring value to suppliers, thus enhancing trust and relationships, or to exploit a strong position, thus forcing other suppliers to adopt the BCT system.

4.2.2. BCT's impact on formal mechanisms for information flows

BCT facilitates the creation of formal mechanisms—that is, structured processes that regulate how information is shared and managed among players in the supply network; this results in data consistency and immutability and to formalized interactions. First, BCT promotes the digitization of operations within supply chains, thereby helping in overcoming the existing digital divide in the agri-food industry. Furthermore, it facilitates the coordinated management of interactions among different actors; it is thus a valuable element for information exchange and underscoring reciprocity, as BCT encourages cooperation among actors, thereby enhancing operational efficiency and information exchange.

Second, BCT has the capacity to reduce reliance on traditional physical control, such as inspections and audits, which are traditionally required in agri-food industries and carried out to ensure product integrity and authenticity. BCT implementation streamlines processes through digital means. As mentioned by the Ernst & Young consultant, who has been involved in designing and implementing several BCT projects in agri-food, Carrefour leverages digital tools by using a digital dashboard that provides real-time access to verified data stored on the BCT to monitor and verify each batch of chicken. In this sense, BCT plays an important role in rethinking data sharing and data management practices, thereby fostering operational efficiency. In fact, this mechanism leads to a substantial reduction in the time frames associated with quality-control activities. Whereas previously, these activities were labor-intensive and time-consuming, often requiring extensive reconciliations, BCT enables companies to streamline data collection processes significantly through the seamless tracking and identification of specific batches, herds, or individual units of produce. This level of precision is particularly valuable in those areas subject to contamination or where product recalls are necessary. Thus, BCT-based systems offer a reliable mechanism for precisely identifying and surgically addressing issues within the supply chain; this in turn enhances overall operational efficiency and streamlines the data exchange flow.

Third, data validation and certification mechanisms serve as infrastructures governing data exchange and handling. These mechanisms include protocols aimed at ensuring that accurate and reliable information is exchanged among supply chain actors. Formal mechanisms have an impact on trust and on the quality of relationships because they provide clarity and foster trustworthiness, thus also enhancing transparency and credibility and promoting fairness, equity, and mutual benefits in the buyer–supplier interaction. From the collected data, there is an agreement concerning what mechanisms must be in place to ensure that data entry is accurate and truthful. Notably, four levels of mechanisms can be identified.

The first level is a relational one, labeled as "reputational risk." According to one interviewee, *"BCT is a deterrent because it connects the data with the company['s] reputation. […] If there is an error, it goes to the good faith/value of the player who declared it. It is counterproductive to declare something that does not reflect reality"* (IT consultant - Birra Peroni). However, this level alone, being a level of self-control of internal data, is not sufficient to ensure the accuracy of inputs entered into the BCT, thus necessitating other levels. The second level, the "control through documents" level, entails the formal control of entered data through control bodies and authorities (i.e., the Italian Ministry of Agriculture, consortia, producers' organizations, etc.), especially for products with PDO. This level is complemented by the third "technological level" of control associated with BCT, which refers to the dedicated software provided by Ernst & Young and the alert systems in place that check entered data and report errors if abnormal quantities are entered. If the data entered is correct and does not generate an alert, the BCT platform generates unique BCT codes, and the platform is able to transform data into certificates. The fourth level, "automation for truthfulness," is achieved through Industry 4.0-enabling technologies, such as the Internet of Things and sensors which minimize master data errors directly at the source. By applying Industry 4.0 technologies directly to production machines, data is transferred directly from the machinery to the software. Agri-food supply chains are increasingly moving toward automated supply chains, and insights at this level are provided by consultants, who refer to projects they have developed with stronger players (i.e., Bofrost). The case studies selected have not reached such a level of control, despite their ongoing efforts in digital transformation. For example, Spinosa is currently working on an Industry 4.0 plant which, in the coming years, will realize the full potential of BCT.

Fourth, smart contracts enable a more standardized information flow between customers and suppliers compared to traditional document exchanges, including digital ones; this streamlines data exchange, makes it faster, and—above all—does not allow for subjectivity in data entry and data transfer. As a result, data exchange is assimilated to an automatism that makes the flow predictable.

Lastly, and connected to the previous point, BCT helps to reduce customer–supplier disputes regarding purchases and payments. Indeed, BCT supports the financial management of the documentation of flows between customers and suppliers. *"What an ERP does for a single company, i.e., connect[ing] different company functions, the blockchain can do for supply chains. The more actors there are to coordinate, the greater the value of the BCT"* (IT Specialist - Placido Volpone). Through smart contracts, different systems in place at different players can be integrated in an immutable and tamperproof manner, as *"one of the companies adds the order and it automatically goes to the other company, the prices are already encoded in a smart contract, so there's no negotiation, there's no reconciliation, there's less email, less ex-post controls"* (IT Specialist - Placido Volpone).

4.2.3. BCT's impact on the quality of information flows and communication

BCT also transforms the quality of information flows and communication. In addition to the inherent technical features of the technology, equally significant contributing factors are that BCT enables disintermediation, enhances credibility and negotiating power, improves communication among supply chain actors, and drives the development of new skills.

Disintermediation, facilitated by the implementation of BCT, reshapes traditional control and certification processes within the agri-food supply chain. Traditionally, certification bodies served as intermediaries entrusted with verifying compliance with quality standards. However, in recent years, the perceived reliability of these actors has experienced a decline: *"Before, you trusted the certification body, but now the trust in these bodies has waned for various reasons. […] In this way [through BCT], we can regain a centrality and a certainty. Having said that, our supply chains are the most controlled in the world compared to what happens outside Italy; however, distorting phenomena still exist"* (IT consultant - Birra Peroni/Ernst & Young). In this vein, BCT serves as a solution leading to disintermediation as, by leveraging BCT, companies can sidestep traditional certification intermediaries and demonstrate compliance directly through transparent and tamperproof records. This shift toward disintermediation facilitates more efficient and reliable quality control mechanisms, thereby strengthening relationships among supply chain actors. At the same time, BCT has the potential to restore trust in certification processes by providing transparent and immutable records of compliance.

Credibility and negotiating power are two positive outcomes stemming from BCT adoption. The digitization process not only serves to streamline operations but also provides validation and increased confidence to the individuals involved, resulting in improved profit margins. The resulting transparency, trust, and reassurance also contribute to stronger relationships among stakeholders while fostering a feeling of cohesion and mutual reliance. Moreover, from an industry perspective, the transparency and mutual reliance enabled by BCT can serve as a strategic lever when engaging with large-scale distributors. By offering superior products enriched with comprehensive information, companies can gain a competitive edge in negotiations with these big players and command higher prices within the whole supply chain network.

Improved communication is underscored by the comprehensive tracing of product origins, as enabled by BCT. This goes far beyond traditional traceability systems based merely on transport documents and, therefore, plays a positive role in ensuring transparency and gaining consumer trust. This heightened level of traceability facilitates communication among supply chain actors and guarantees consistency and reliability in data sharing, thereby strengthening relationships. *"We have realized that with the blockchain we are able to communicate better [and] more reliably with all the players in the supply chain"* (Marketing Manager - Spinosa).

A final area leading to improved quality of relationships and communication is linked to the development of new capabilities through which to efficiently operate BCT. In the case studies under investigation, BCT has not led to the selection and hiring of new personnel, but rather to the redefinition of existing competences and skills. Communication and marketing experts have been trained to facilitate effective storytelling via BCT for the selected products, while digital and technical skills have been developed by employees working in the production and quality departments.

5. Discussion of findings

5.1. Understanding the impact of BCT adoption and implementation on relationships in the agri-food sector

The empirical analysis provides valuable insights into the impact of BCT adoption and implementation on relationships in the agri-food sector. By linking these findings with the theoretical background outlined in Section 2, we can reflect on the key emerging themes identified from the literature review.

The first theme explores the **rethinking of the role of trust in supply chain relationships influenced by the adoption of BCT**. Consistent with existing literature, BCT serves as a deterrent to fraudulent behavior among supply chain actors (Pakseresht et al., 2023) due to the immutability of its data blocks, thereby increasing the level of transparency in communication. Additionally, by facilitating time savings, error reduction, and increased discretion in the buyer–supplier information exchange, it plays a pivotal role in strengthening trust.

Trust is enhanced by BCT in already established B2B relationships characterized by shared organizational and management routines. However, BCT does not substitute the need for trust in newly established relationships (Petersen, 2022). It supports its growth and development, as it can consolidate relationships based on the inability to subvert what is communicated externally (Brookbanks and Parry, 2022). The validity

Table 4
– Summary of beneficial exchanges, norms, and principles emerging from the empirical findings.

Category	Empirical findings	Contribution to SET
Beneficial exchange	● Mutual value creation ● Strengthening of supplier relationships through digitization ● Coordination and alignment within the supply network ● Differentiation and positioning	The concepts of mutual value creation and the strengthening of supplier relationships through digitization underscore the principle of reciprocity and mutual benefits, which is a central tenet of SET. Leveraging digital technologies—particularly through BCT—could enhance scalability, automate routine tasks, provide better visibility, and increase information sharing and transparency, thereby facilitating suppliers' alignment with target objectives while also decreasing coordination costs and efforts (Luzzini et al., 2024; Schmidt and Wagner, 2019). This contributes to the focus of SET on reducing transaction costs in exchanges, along with its emphasis on information symmetry and trust. Benefits arise from buyers' willingness to pay a premium price for suppliers that disclose immutable information (Vinayavekhin et al., 2024). This willingness stems from the increased trust and perceived value associated with transparent and reliable data. By leveraging BCT to provide immutable records, suppliers can differentiate themselves in the market by positioning their products as more trustworthy and of higher quality compared to competitors who do not offer such transparency.
Norms	● Digitization of operations and digital immutability ● Overcoming physical control ● Implementation of data validation mechanisms 1. Relational or "reputational risk" level 2. "Control through documents" level 3. Technological level 4. "Automation for truthfulness" level ● Automation through smart contracts	The norms identified reduce transaction costs and increase efficiency, supporting SET's core principles of evaluating exchanges based on their costs and benefits. In addition, standardized processes and validation mechanisms promote fairness and equity in exchanges, thus ensuring symmetries among parties (Ellis et al., 2023). The digitization of operations requires digital readiness, which is an essential prerequisite since the integration of advanced digital technologies is related to substantial challenges (Flechsig et al., 2022). This readiness impacts the ability of parties to engage in and benefit from technologically mediated exchange.
Principles	● Disintermediation ● Credibility and negotiating power ● Improved communication, ensuring consistency and reliability in data sharing ● Capabilities development	Data validation mechanisms, which rely on the self-validation of transactions without a trusted intermediary, can reduce dependence on intermediaries and enhance direct relationships between buyers and suppliers, possibly shifting power dynamics (Parviziomran and Elliot, 2023; Schmidt and Wagner, 2019). The increased transparency and immutability of information, as well as improved consistency and reliability in data sharing, can shift power positions and alter power dynamics in relationships, leading to more balanced exchanges and a reduction in opportunistic behavior (Huang and Chiu, 2018). The development of BCT-related capabilities can contribute to the development of relationship-specific assets and thus lead to increased interdependence and more committed relationships.

of such results holds to the extent that the willingness and capability to jointly implement BCT is shared among all actors in the networks, underscoring the importance of cooperation (Anderson and Narus, 1990). BCT's value creation is maximized when it is widely adopted across the supply chain (Schmidt and Wagner, 2019), highlighting the necessity of a shared BCT implementation strategy (Min, 2019).

The effectiveness of BCT also relies on how supply chain actors perceive its benefits and align with existing supply chain policies. In more concentrated market contexts, populated by big players with a marked ability to influence a large number of suppliers and sub-suppliers, bargaining power emerges as a coercive lever for small suppliers who would otherwise not join the BCT project. This insight goes against existing evidence on the key role played by BCT in the democratization of the supply process and in establishing a fairer balance in relationships between big buyers and small farmers (Scuderi et al., 2019), as well as the importance of relational norms in governing interactions and curtailing the abuse of power (Lambe et al., 2001). Small suppliers may view joining the BCT projects as a costly decision (Bracci et al., 2022), both in economic and organizational-managerial terms, as it requires them to adopt new digital devices, train staff to use the new technology, and devote more time and attention to data entry and transfer.

Our adoption of a SET-based perspective results in deeper insights into the mechanisms that lead to a rethinking of trust following the adoption of BCT. Notably, when looking at beneficial exchanges, the data provide insights regarding: (i) mutual value creation; (ii) the strengthening of relationships through digitization; (iii) coordination and alignment within the supply chain; and (iv) differentiation and positioning (see also the first row of Table 4).

Mutual value creation is enabled by BCT, as reliable product authentication has a direct impact on trust-building among actors in the supply chain. Wholesalers and retailers can sell certified Italian products at a premium price while producers can gain access to new foreign markets, thereby strengthening their position within the supply chain. At the same time, upstream actors experience enhanced credibility thanks to BCT adoption, which also fosters a sense of ownership and empowerment as they assume an active role in the supply chain. This can result in new supply chain contracts (Min, 2019) that are built on the mutual trust enabled by BCT and which result in greater revenue and recognition, as observed at Spinosa.

The strengthening of relationships through digitization is a main output of BCT implementation; this is in stark contrast to the skepticism toward BCT that was previously prevalent in agri-food sectors among actors upstream of the supply chain (Treiblmaier et al., 2021). Here, BCT, coupled with the related digital tools required for its functioning, brought about positive results that improved individual actors' operational efficiency and enhanced fruitful interactions, leading to an increase in mutual trust. Thus, the digitization driven by BCT fostered an atmosphere of collaboration, transparency, and fairness.

Building on the insights regarding digitalization, we find that coordination and alignment within the supply chain emerge both as drivers and the results of BCT adoption. Existing trust plays a key role, which is simultaneously redefined through BCT. On the one hand, the digitization process initiated by BCT requires consensus among all actors, with existing trust serving as a catalyst to trigger such digital transformation. On the other hand, BCT exemplifies an "incentive" to embark on digitization, offering the potential for the premium pricing of products and enhanced coordination within the supply chain when a clear BCT digital strategy is shared (Rogerson and Parry, 2020).

Finally, BCT allows for enhanced product positioning, differentiation, and brand reputations, especially in markets characterized by narrow margins. In such a context, a shared BCT strategy can effectively support a repositioning and/or differentiation strategy (Köhler et al., 2021); this can lead to an increased willingness to pay (Vinayavekhin et al., 2024) and thus to higher remuneration for all actors in the supply chain.

The second theme identified is the **enhancement of information-sharing and flow mechanisms through the adoption of BCT**. BCT acts as an enabler of information flow standardization through smart contracts, making data exchange more predictable and reducing reliance on informal rules and written procedures (Petersen, 2022; Zhao et al., 2019). Indeed, BCT streamlines data exchange, thereby making it

faster, and—most importantly—eliminating subjectivity in data entry and transfer. Furthermore, it also reduces customer–supplier arguments over purchases, payments, and disputes by supporting the financial management of documentation between the customer and supplier.

A further interesting element is constituted by the concept of disintermediation (Petersen, 2022; Saurabh and Dey, 2021). Although certifying bodies remain necessary for animal welfare and other standards, smart contracts can automate processes through automated alerts for non-compliance, replacing visiting a center, compiling a checklist, and providing certification marks. Certifiers will maintain their role while the data supporting certification are collected and tracked, providing additional proof of compliance with required standards. This advancement significantly improves reliability for both consumers and the entire supply chain. Furthermore, supply chain contracts could help BCT reduce the complexity of the supply chain and achieve the most in-depth and accurate level of traceability both upstream and downstream, thereby working toward the full integration of information flows on the BCT-based data exchange platform.

One interesting insight emerging from the interviews regards the role of BCT in the supply chain, which seems to mirror, at the supply chain level, the role played by enterprise resource planning (ERP) at the firm level. BCT integrates logistics and information flows and supports coordination among different supply chain actors. In this sense, the more actors there are to coordinate, the greater the value of BCT. BCT allows for the better integration of data between buyers and suppliers, which increases the level of transparency and clarity and strengthens existing ties. This holds particular relevance for the food supply chain, which is characterized by a multi-actor nature, complexity, and the interdependence of processes in its main stages (Caro et al., 2018).

Filtering our data through the SET lens allows us to identify the norms that enhance information-sharing and flow mechanisms in supply chain relationships through the adoption of BCT. The identified principles are: (i) digitization of operations and digital immutability; (ii) overcoming of physical control; (iii) data validation mechanisms; and (iv) automation through smart contracts (see also the second row of Table 4).

The digitization of operations within the supply chain enables the coordinated management of interactions among actors. On the one hand, the digitization of data collection bridges the existing digital divide in the agri-food sector, facilitating the exchange of information and highlighting reciprocity among actors. Information-sharing processes become more reliable and trusted, as BCT facilitates the exchange of critical data without the risk of manipulation, thereby fostering transparent and accountable interactions.

The norm of overcoming physical control thanks to BCT significantly enhances information-sharing and flow mechanisms. Real-time access to verified data stored on blockchain reshapes data sharing and management, leading to a significant reduction in the time dedicated to quality control activities while providing a more efficient and precise method for identifying and targeting potential issues (Casino et al., 2021). Additionally, the numerous cross-validation mechanisms for data inputs and ex-post alerting systems serve as critical infrastructure; they govern and control data exchange and data handling while impacting trust and relationship quality by enabling accurate and reliable information exchange (Li et al., 2021; O'Leary, 2017). In industrial production settings, BCT application needs to be as unobtrusive as possible so as to avoid slowing down production. Therefore, the more data collection is automated through integrated platforms and control algorithms, the more efficient the system becomes. Similarly, the standardization and automation of information flow exchanges via smart contracts ensures fairness and equity in interactions, highlighting the mutual benefits emerging in such exchanges.

The third theme focuses on the **optimization of the quality of information flows and communication dynamics through the adoption of BCT**. The analysis demonstrates the role played by BCT in organizing and managing big data and optimizing internal resources, especially with regard to the quality of information related to food safety and traceability. This reduces information asymmetries between the supplier and customer, thereby improving the quality of information and the relationships themselves (Brookbanks and Parry, 2022; Köhler et al., 2021). These elements help manage the complexity of the supply chain and strengthen customer–supplier relationships on the basis of transparency and trust. Furthermore, we note that the improved quality of information allows the manufacturer to make better sales forecasts (especially in terms of the production mix); this supports purchasing and production planning, thus supporting the decision-making process related to purchasing and production.

BCT provides a platform for data entry and circulation, which can generate an advantage regarding the quality of information useful for management decision-making. The availability of a structured data history makes it possible to make projections on quantities, non-conformities, and other invaluable data to make assumptions about product and process improvement. This evidence suggests that a form of data-driven management based on data collected through BCT (Lezoche et al., 2020) is required; this can also aid in the development of eco-sustainability-oriented solutions aimed at improving the quality of the relationship with downstream actors in the supply chain; that is, both distributors and final consumers.

In this sense, we can posit that there is room for improvement in the functioning of BCT in the agri-food industry (Rana et al., 2021). Although transparency and food safety are stringently regulated in Italy and the European Union through control and certification standards and practices (Regattieri et al., 2007), challenges remain concerning the limitations of available tools and the complex articulation of the supply chain, which is composed of multiple actors and logistical information flows that connect one to the other. Without a clear and shared standard capable of synthesizing quality information at each step and managing its complexity, there is a risk connected to certifying food as safe and transparent based on generic information. In Spinosa's experience, traceability built and managed solely on the basis of transportation documents certifying the entry of goods (i.e., milk) at a given time from a given supplier is insufficient for the purposes of transparency and consumer assurance. To make the data consistent for traceability and control purposes, it is necessary to be able to trace back from the batch of milk received to even the name of the bull that impregnated the buffalo milked; in addition, a parceling out of batches is needed to control and guarantee all stages of dairy processing. Such in-depth and meticulous traceability is extremely onerous and challenging. Upstream, a strong relationship is needed with numerous suppliers and subcontractors, as this will allow for the sharing of digital tools capable of collecting, structuring, and circulating a massive amount of data daily; this highlights the importance of principles such as cooperation and dependence (Lambe et al., 2001). Within the production process, organization and digital skills are needed to manage, analyze, and link this massive amount of data.

Building on our general discussion of the impact of BCT on information flow quality and communication dynamics, SET allows us to highlight insights regarding how these are optimized and thus impact relationships. In this case, the analysis has led to the identification of key principles (which are also detailed in the third row of Table 4). These are: (i) disintermediation; (ii) credibility and negotiating power; (iii) improved communication, ensuring consistency and reliability in data sharing; and (iv) capabilities development.

The reshaping of traditional control and certification processes through BCT leads to increased disintermediation, with companies being able to directly demonstrate compliance through transparent and tamperproof records. This can reduce dependence on intermediaries and enhance direct relationships between buyers and suppliers, possibly shifting power dynamics (Parviziomran and Elliot, 2023; Schmidt and Wagner, 2019).

Credibility and negotiating power are two key outputs of BCT. This is because the digitization process, in addition to streamlining operations,

also provides rewards and reassurance to the implementing actors, which contributes to stronger cohesion and mutual reliance among supply chain participants. Negotiating power is derived from the exploitation of BCT as a strategic lever in the interaction with large-scale distributors: BCT adds information and value to products, and producers can thus command higher prices (Samoggia and Beyhan, 2022).

BCT also facilitates the comprehensive tracing of products, far beyond traditional traceability systems (Casino et al., 2021), thus ensuring transparency and increasing trust. Such consistency and reliability in data sharing leads to positive and more balanced interaction dynamics and a strengthening of supply chain relationships, while reducing opportunistic behavior (Huang and Chiu, 2018).

Finally, the investment in new skills and competencies required to efficiently use BCT has pushed companies to develop and enhance their digital, as well as communication and collaboration, capabilities. Communication and marketing experts have therefore been trained to communicate the benefits of BCT-related products to stakeholders and consumers (Rogerson and Parry, 2020). This new set of skills fosters more effective communication and collaboration among supply chain actors.

5.2. Managerial implications

Our empirical research results in numerous managerial implications, which can be summarized into three main take-home points:

1. *Without the digitization of the supply network, there is no BCT!* Effective implementation of BCT depends on a supply chain-shared digitization strategy (Rogerson and Parry, 2020). Leveraging enhanced trust from BCT managers should incentivize actors upstream of the supply chain to initiate digitization processes to address the digital divide that characterizes agri-food supply chains and overcome the trade-off between opportunistic behavior and transparency. In a longer-term perspective, automation should be encouraged to facilitate the implementation of data validation mechanisms that ensure the accuracy and veracity of data; this will help realize BCT's full potential.
2. *BCT is to the supply chain what ERP is to the enterprise!* BCT represents an opportunity for horizontal business aggregations (i.e., consortia, producers' organizations, etc.) to promote the digitization of the production and logistical processes of their member companies. BCT, by increasing the credibility and reliability of the processor, can be used as a lever for the vertical integration of the most fragmented supply chains through BCT-based supply chain agreements. Business aggregations can count on a supportive policy landscape, as Italian regional governments are providing funding sources for the digitization of small and medium-sized enterprises.
3. *All for one and one for all!* Managers should exploit the strengthening of relationships facilitated by BCT to promote integration among upstream actors. Such cooperation and integration will increase the negotiating power of the supply chain and improve channel relations with the downstream distribution system. BCT should be used to optimize logistics and operating costs and not only as a marketing instrument for consumers; thus, actors should value BCT in terms of market and selling price.

These implications can be translated into actionable guidance for managers operating in agri-food industries. Specifically, they underscore the importance of adopting a strategic, collaborative, and capability-driven approach to effectively exploit the potential of BCT. First, managers should prioritize digitization efforts and develop a shared digitization strategy in alignment with supply chain partners to facilitate the adoption and implementation of BCT. Second, managers should strategically use BCT and capitalize on this technology—especially in terms of product authenticity enhancement, traceability, and brand reputation—for positioning and differentiation purposes. In markets characterized by narrow profit margins, BCT can be a valuable tool supporting product positioning and differentiation strategies, potentially leading to premium pricing opportunities. Third, efficient and effective BCT implementation necessitates investments in training programs to enhance digital skills, communication, and collaboration capabilities among employees.

6. Conclusion

This research conducted an exploratory study to identify and empirically investigate the salient elements of the link between BCT and relationships in agri-food. While previous studies have primarily focused on specific aspects of BCT adoption, such as supply chain visibility and traceability, our study shifts the focus to the dynamics and quality of relationships within the network. In particular, to address the research question (*What is the effect of BCT on supply chain relationships?*), this study investigates early BCT adopters in the wine, dairy, and beer sectors in Italy.

The results of this study indicate that the functionality of BCT operates on a dual track; that is, there is the automation of supply chain contracts and supply chain operational efficiency, on the one hand, and the increased quality of supply chain relationships, on the other. The data show that supply chain coordination is required for BCT to be effective. In highly concentrated sectors, this highlights the contractual power exerted by big players (Fan et al., 2022), while in more fragmented and dispersed industries the role of persuasion, relationships, and supply chain contracts emerge as key. The latter is linked to a common issue that emerged from the interviews, where the interviewees described having encountered difficulties in convincing suppliers, companies, and other actors to adopt BCT in their processes; this was also due to a general distrust in digital technologies. This hampers the shared governance potentiality of technology (Dehghani et al., 2022) to make the agri-food supply chain more governable. A further result concerns the variables that increase the criticality and relevance of BCT; that is, the size of the producers (wineries, breweries, dairies, etc.), the variety of the raw material (i.e., grape varieties), and the diversity of its origins.

From a theoretical perspective, this research contributes to the growing literature on BCT adoption by analyzing the overlooked perspective of how BCT changes the nature and quality of relationships within the network (Treiblmaier, 2018). In particular, the case study analysis contributes to filling a gap identified in the literature; that is, it moves away from the predominant focus on the impact of BCT on the downstream supply chain and its impact on customer relationships (Ghose, 2018; Köhler and Pizzol, 2020). Our research provides a novel perspective on upstream relationships in supply chains, thus contributing to the creation of a comprehensive level of blockchain exploration from a management perspective. Second, it provides an initial contribution regarding the benefits, challenges, and potential of BCT adoption in the agri-food industry, which is characterized by a lack of transparency and high vulnerability and costs (Feng et al., 2020; Rejeb et al., 2020; Sourabh and Dey, 2021; Stranieri et al., 2021). The use of SET provides a novel and fresh perspective on how technological advancements shape interaction processes among supply chain actors in the agri-food industry. It further adds to existing studies that examine specific dimensions of BCT implementation (i.e., supply chain visibility, traceability, and the fight against counterfeiting) by providing a comprehensive analysis of relationships. Through the identification of beneficial exchanges, norms, and principles, this study makes significant contributions in the areas of trust, formal mechanisms for information exchange, and the quality of information flows (Lambe et al., 2001).

A number of key insights emerge from this study. First, BCT fosters trust at the start of new relationships and can partially replace it in established relationships; therefore, it can lead to a preference for transparency over opportunism (Huang and Chiu, 2018; Petersen, 2022). Second, in more concentrated supply chains, the adoption of BCT

by suppliers is induced by the coercive bargaining power of large players, while in more fragmented contexts it is driven by horizontal coordination mechanisms and supply chain contracts; therefore, supply chain concentration can influence BCT's effectiveness. Third, BCT enables companies to overcome the digital divide and facilitates the integration of logistics flows with suppliers upstream. Fourth, BCT facilitates improvements in performance control in the procurement and transformation phases; therefore, it can influence the optimization of operational and logistics costs upstream. Fifth, it reduces disputes with suppliers regarding purchases and payments and, by increasing the precision of the information shared, supports quality control. Sixth, it supports product policy and can positively influence eco-sustainable choices (Köhler et al., 2021).

This study has some limitations, which constitute avenues for future research. The two main limitations are related to the nature and size of the selected companies. First, this research is solely based on case studies of producers. Second, the companies selected in the wine sector (i.e., Cantine Paololeo, Torrevento, Casa Girelli, Placido Volpone, and Ricci Curbastro) are small family-run firms, whose size and nature can sometimes be deemed as unsuitable when researching the implications of BCT adoption. Thus, including larger wineries that vinify large quantities of grapes from several suppliers located in different territories in the sample could provide more insights into the upstream value of BCT as an innovative tool. A further limitation results from the fact that it is not possible to generalize our results to the whole agri-food industry. Indeed, as this study focuses on only a few select supply chains in a specific geographical area (i.e., Italy), it is not possible to draw broader conclusions because other regions and supply chains are characterized by different dynamics, power distributions, and pressures.

There are several avenues for future research that this study has touched upon. First, future research could conduct an in-depth exploration, through quantitative analysis, of the link between the size of agri-food processors and the efficiency of BCT. Second, this study has shown, from an intraorganizational perspective, that there is a need to "upskill" existing skills and resources both from a digital perspective and from a marketing and communication one. Future research could focus on this intraorganizational matter by analyzing how and which skills and resources need to be developed and what possible training programs could be designed to ensure coordination and positive outcomes in supply chain relationships following the adoption of BCT. Third, in line with recent research (Huang et al., 2022; Kouhizadeh et al., 2021; Paul et al., 2022; Yadav and Singh, 2020), this study provides preliminary insights into the indirect link between BCT, enhanced environmental sustainability, and the circularity of production and processes. Future studies could dig deeper into this facet to explore the potentiality of BCT for relationships pursuing circularity (Di Mauro et al., 2024; Fang et al., 2024). Finally, our findings and managerial implications suggest a potential temporal sequence among the identified norms and principles associated with BCT adoption in agri-food supply chains. For instance, the norm of "digitization of operations and digital immutability" appears to act as a precursor for other emerging norms, such as those related to overcoming physical control and the implications of data validation mechanisms. Future research could therefore investigate the existence of such a hierarchical or concatenated structure among the various norms and principles.

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Raffaele Silvestri: Writing – original draft, Supervision, Investigation, Formal analysis, Conceptualization. **Elisa Carloni:** Writing – original draft, Methodology, Investigation, Formal analysis, Conceptualization. **Domenico Morrone:** Writing – review & editing, Conceptualization. **Savino Santovito:** Writing – review & editing.

Declaration of competing interest

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

Data availability

The data that has been used is confidential.

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