Operations Management Research (2023) 16:1562–1576
https://doi.org/10.1007/s12063-023-00377-w

Multi-tier supply chain behavior with blockchain technology: evidence from a frozen fish supply chain

Ulpan Tokkozhina[1,2,3] · **Ana Lucia Martins**[1,2] · **Joao C. Ferreira**[2,3,4,5]

Received: 14 September 2022 / Revised: 21 March 2023 / Accepted: 23 April 2023 / Published online: 28 April 2023

Abstract
Relationships in multi-tier supply chains (MTSCs) are complex and require constant information sharing. For MTSCs involved in perishable product distribution, blockchain technology (BCT) is one of the most promising technologies that can ensure products' traceability and safety. This study examines a Portuguese MTSC for frozen fish products piloting BCT adoption for its supply chain (SC) practices. The goal is therefore to explore the consequences of information availability inherent for BCT adoption pilots in the SC context. This study follows a mixed-method approach, with qualitative and quantitative data collection techniques. Three semi-structured interviews with players from a single frozen fish SC, including supplier, transporter, and retailer were conducted. MAXQDA Analytics Pro 2022 software was used for further coding and data analysis. An online survey among retail chain consumers was conducted resulting in 112 responses. Regression analysis and Pearson correlation test were further performed via IBM SPSS Statistics software. Data collection for both parts took place between December 2021 and July 2022. This study explores four layers in the SC– including supplier, transporter, retailer and final consumer. Findings revealed a current lack of extensive and detailed information from upper tiers regarding products' characteristics. Despite being hyped as a "trust-enabling" technology, BCT was found not to eliminate the need for trustful relationships between players prior to adoption, as information input requires human intervention. Even in those cases when the traceability option is not of major interest to final consumers, findings revealed a higher probability of purchasing fish products that have traceable information available.

Keywords Blockchain technology · Multi-tier supply chains · Final consumers · Information sharing · Frozen fish products · Mixed-method approach

1 Introduction

In the current dynamic worldwide environment, supply chains (SCs) face with a vast number of challenges, where demand forecasting is hampered by inaccurate historical demand (Perera et al. 2019; Siddiqui et al. 2022), gaps in communication between SC players result in poor visibility, thus creating a higher risk of unexpected issues arising (Gray and Purdy 2018). SCs today may be characterized as long and complex, therefore the bullwhip effect arises as a result of poor communication between entities, leaving a negative imprint on the overall SC operations, thus highlighting a need to reconsider ways of using information in a more effective and efficient way for a better SC coordination and overall performance improvement (Ojha 2019; Tliche et al. 2023). Fast moving business environment builds an additional complexity to SC collaboration, considering the diversity of social and organizational cultures (Huang et al.

✉ Ulpan Tokkozhina
ulpan_tokkozhina@iscte-iul.pt

Ana Lucia Martins
almartins@iscte-iul.pt

Joao C. Ferreira
jcafa@iscte-iul.pt

1 Business Research Unit (BRU-IUL), Lisbon, Portugal

2 Instituto Universitário de Lisboa (ISCTE-IUL), Lisbon 1649-026, Portugal

3 Inov Inesc Inovação—Instituto de Novas Tecnologias, Lisbon 1000-029, Portugal

4 Information Sciences and Technologies and Architecture Research Centre (ISTAR-IUL), Lisbon, Portugal

5 Logistics, Molde University College, Molde NO-6410, Norway

2020). End-to-end SCs consist of multi-tier supply chains (MTSCs), where a massive amount of data needs to be gathered and analyzed, which requires a transparent workflow for information sharing among all levels of the MTSC (Khan et al. 2021a); thus, collaboration is an essential component that may address the current SC challenges.

Moreover, the nature of the products/services flowing in the SC influences collaborative behaviors, as some cases might require closer collaboration between parties. Compared to other product SCs, food supply chains (FSCs) are objectively more complex, as the perishability and short shelf life of products create more difficulties for management (Aung and Chang 2014). In FSCs visibility is crucial and more attention should be paid to improving food safety quality along the SC (Nacul and Revoredo-Giha 2022), especially for perishable and sensitive foods. Due to the various occurrences worldwide of food counterfeiting and contamination, the need for efficient SC coordination and revised management models is increasing to ensure consumers' health and safety, as well as to comply with the various international regulations (Cocco et al. 2021). Innovative solutions using novel technologies of Industry 4.0 are generally considered for the enhancement of business practices (Cimini et al. 2020), but when it comes to the visibility and the speed of information sharing and verification in FSCs, technologies such as Internet of things (IoT) (Pal and Kant 2018; Madumidha et al. 2019; Yadav et al. 2020; Rejeb et al. 2021a), drones (Dutta and Mitra 2021), artificial intelligence (AI) and augmented reality (AR) (Kittipanya-Ngam and Tan 2020) are being applied.

One such type of technology that allows instant information sharing in a decentralized way is blockchain technology (BCT). BCT is a distributed ledger technology with the ability to store and share information in an immutable way across a network of participants (Tian 2017) and is referred to as a "potential breakthrough in the future supply chain" (Khan and Yu 2021, p.2). BCT use in SC practices allows businesses to manage processes more efficiently and effectively (Sternberg et al. 2021), as the BCT ledger guarantees the authenticity of the data and enables the tracking of the production and storage conditions of a particular product back to its source (Kamble et al. 2019a). BCT applications for FSCs are becoming more popular, both in industry and academia. Due to the early stages of technology adoption, BCT is currently more common among larger organizations than small and medium ones (Khan et al. 2021c). One of such most popular real-world applications today is IBM's Food Trust solution, which is a platform based on BCT that connects participants of FSCs worldwide with shared record data (ibm.com). In the academic literature, there is a vast number of proposals for FSC solutions based on the BCT platform concept. Research interests among scholars include BCT-based proposals for halal meat (Rejeb 2018; Sumarliah et al. 2023), the traceability of dairy products (Casino et al. 2021), fish products and marine conservation (Howson 2020; Tokkozhina et al. 2020; Callinan et al. 2022), perishable food products (Kayikci et al. 2021), coffee (Kramer et al. 2021) and smart-contract-enabled architectures for wine SCs (Tokkozhina et al. 2021), among others.

There is a significant positive influence of SC collaboration on stakeholder trust and visibility (Baah et al. 2021) and a positive impact of BCT implementation on eco-environmental practices and organizational performance in the context of cross-border SC operations (Khan et al. 2021b), however there is still a gap for future studies to explore what effect technological changes and the characteristics of products have on SC practices, as well as integration level of BCT on organizational level. BCT impacts on collaboration between SC partners through information sharing processes Rejeb et al. 2021a conceptualized proposition for BCT-enabled MTSCs was performed (Agrawal et al. 2021), as well literature review approach towards the exploration of BCT integration in a complex MTSCs environment (Najjar et al. 2022; Wang et al. 2022), leaving space for further empirical research conducted in the field. In the context of FSC a BCT project undertaken by a food retailer, involving different stages of the three SCs was performed (Stranieri et al. 2020), the possible effect of BCT adoption for sustainable SC architecture for wine SC was simulated and analyzed (Saurabh and Dey 2021); similarly, therefore, it would be worthwhile studying the real-life experience of MTSC players in a food supply network that is already adopting BCT to see the real effect. Although there are already some triadic SC cases investigated in various industries, including food (Mesic et al. 2018), furniture (Sales-Vivo et al. 2020), machinery and transportation (Swierczek 2020), and tourism (Fong et al. 2021), among others, the academic literature lacks the exploration of more real-case of SC relationships that go beyond that of the buyer–supplier. Callinan et al. (2022) highlighted the current lack of empirical research (using, for instance, focus groups and interviews) on BCT enablers, barriers, and adoption factors in the fish industry. Thus, a gap in current knowledge remains in terms of understanding the broader picture for end-to-end SCs, which go beyond traditional dyadic and triadic relationships, especially when talking about novel technology adoption in such a specific industry as frozen fish, it is crucial to understand how information flows in a MTSC environment, and what the potential values are that this traceability technology may bring to final customers.

With the purpose to contribute to these gaps, the goal of this study is to explore the consequences of information availability that are inherent for BCT adoption pilots in the SCM context. In doing so, this paper aims to investigate

players' views of a MTSC on the contributions and expectations resulting from information availability, and whether the motivations among the four tiers of SC participants (supplier, transporter, retailer and final consumer) regarding BCT adoption differ through the SC. The case of a Portuguese SC involved in frozen fish products will be used. Additionally, the perspective of frozen fish consumers of this SC was investigated to assess whether the value that traceability technology can bring to the product is recognized and desired by customers. Accordingly, this study aims to answer the following research questions (RQs):

RQ1 How does the motivation for blockchain technology adoption and the willingness to share information differ throughout a multi-tier supply chain (MTSC)?

RQ2 Is the potential value of traceability information availability recognized by final consumers?

This study uses a mixed-method approach to address the above-mentioned RQs. The first part of the study follows a qualitative approach, conducting semi-structured interviews among a single MTSC, including the supplier, the transporter and the retailer. The second part of the study is following a quantitative approach and is collecting data among final consumers of the retail chain through an online survey. This study aims to contribute to current knowledge by bringing together four different tiers of a single SC involved in the adoption of BCT for frozen fish products and exploring the consequences of information availability that are characteristic of BCT integration.

The remainder of this paper is structured as follows. Section 2 reviews the extant literature on BCT and SC relationships. Section 3 describes the research methodology applied in this study. The findings are presented in Sect. 4 and further discussed in Sect. 5. Finally, Sect. 6 concludes the study, highlighting the main contributions, limitations, and future research directions.

2 Literature review

As stated by (Horvath 2001) "you cannot optimize your own operations until you understand the real-time demands of your customers, as well as the current constraints for your suppliers." This reflects the constant challenge of SCs, where the need for real-time shared information would enable focusing on the optimization of in-house operations.

Mesic et al. (2018) found that all members in a food-related MTSC recognized the importance of the quality and safety of the end products, where final consumers judged the overall attractiveness of products as an essential factor generated by the focal companies. When considering triads (supplier–buyer–customer), the independence of suppliers' actions and negligent attitudes create complexities for the buyer in establishing high-quality relationships across such SCs (Swierczek 2020; Liu et al. 2022a) suggested that, for this reason, the implementation of digital governance platforms is essential to protect players' trust and deal with the behavioral complexity of MTSC collaborations, which over time implies multi-level decision-making.

Through BCT adoption, organizations can ensure secure transactions and processes, which may result in improved efficiency and long-term benefits under the scope of economic, social and environmental aspects (Khan et al. 2022a). BCT is a promising tool to ensure traceability and data integrity; it creates a decentralized environment for SCs where transactions are automated through the use of smart contracts (Juma et al. 2019). With the current growing interest in BCT solutions, it is important to understand what issue is BCT going to address in a specific use case, so decision models for the BCT platform selection can be used by businesses (Farshidi et al. 2020). According to Cao et al. (2022), traditional traceability technologies cannot guarantee a reliable solution for FSCs, because they are not decentralized, meaning that data-holder can willfully change the data in the traceability system, thus compromising accuracy and safety. Whereas in decentralized environments, each player uses BCT as a generic communication and collaboration channel, where each participant can have access to information and its validation on equal terms with any other participant (Menon and Jain 2021). In this context, two types of BCT need to be distinguished: public (or "permissionless"); and private ("permissioned"). In a permissionless environment, every transaction is public, where usually an incentivizing mechanism encourages more participants to join the network. In contrast, in permissioned networks, an invitation must be received to allow one to join; this can be controlled by a consortium of members or by a single central entity (Wang et al. 2019). BCT is an efficient solution for cross-border trade, as it allows a higher throughput and transaction speed (Geneiatakis et al. 2020). As multi-level decision-making is a characteristic of MTSC collaborations, BCT can bring value to the coordination of critical decisions for SCs due to its ability to synchronize data, which potentially results in improved performance (Rejeb et al. 2021b). When considering MTSCs, weak relationships among buyers and suppliers may weaken collaboration when there is a need to focus on social issues (Khan et al. 2021); thus, novel technologies could address the need to establish trust relationships between buyers and suppliers. BCT, when applied to SC transactions, can enhance transparency and trust between MTSCs (Saberi et al. 2019;

Kamble et al. 2019b) as records are immutable and can be verified at any time by any participant.

Nguyen and Li (2022) formulate two main challenges in the context of food SCs - first of all, natural products are mainly perishable, which brings potential risk to harm consumers' health; second, the SC networks themselves are more complex and complicated when it comes to food distribution. Therefore, for food SCs, BCT brings a whole new improved method for product verification throughout the whole distribution process, allowing participants to check provenance information. Kamble et al. (2019a) explained how BCT systems are deployed in SCs through the creation of digital tokens, whereby, at every stage of the value-adding process, the stakeholder assigns a digital token to each asset. As the given asset moves through the SC, the corresponding digital token is also reassigned to the BCT platform (Kamble et al. 2021). Thus, organizations can reinforce the effect of this technology-driven solution by end-to-end tracking of goods locomotion through the entire SC (Khan et al. 2022b). To obtain this extensive level of product visibility, various parts of the SC need to collaborate in BCT adoption; the requirements, therefore, go beyond those of the classical supplier-buyer perspective. For example, using blockchain together with third-party logistics (3PL) allows the consumer to track the food origin and provides entire chain visibility (Johnson et al. 2020; Kafeel et al. 2023) highlight a current lack of managers' understanding of BCT in the SC context, as well as the missing link between the environmental footprint of BCT and the final consumers' attitudes towards it. Collaboration, information sharing, and partners' coordination are the critical factors of BCT implementation in SCs (Kouhizadeh et al. 2020) enabling network organizational capabilities to be strengthened. However, information sharing in MTSCs can be difficult, as according to Wang et al. (2019), organizations are generally skeptical about sharing their information, as it might lead to a loss of competitive advantage. Zheng et al. (2023) found that producers of agricultural products are still hesitant about traceability increasing strategies due to the limited infrastructure of BCT implementation and the high costs of traceability platforms integration into existing operations. From the perspective of complex international SCs, the information-sharing mechanism is also a crucial factor for the overall efficiency evaluation (Juma et al. 2019). Thus, SCs that are willing to innovate with novel traceability-enabling technologies must be ready to accept information sharing across the chain.

Liu et al. (2022b) explored the collaborative development of a BCT-based solution between a core enterprise and SME enabled by the instrumentality of SC contracts, where compared to decentralized decision-making, centralized one showed more ability to increase profits. However, this exploration lacks an angle of downstream SC like final customers, to understand the impact of BCT on customers' interests and purchase decisions. Another recent study conducted by Yerpude et al. (2022) focused on an empirical analysis of parameters influencing a BCT-based digital SC that result in customer retention, collecting data only among managers from the industry that are involved in strategic decision-making. Thus, further investigation of customer interest and retention under this context are needed with the input of customers directly. Another empirical study was conducted by Yadlapalli et al. (2022), where BCT implementation challenges were explored under the scope of multi-stakeholders, however, stakeholders that were used for the investigation were not representatives of a single SC, which still leaves a gap on a MTSC exploration under the context of a single SC. Some other studies, such as the investigation conducted by Behl et al. (2022), focused solely on retailers' perspective regarding readiness to implement BCT, concluding that BCT leads to higher trust and players' motivation level, thus improving SC performance.

3 Methodology

To answer the RQs of this study, a mixed-method approach was used for empirical data collection. First, a Portuguese SC currently piloting BCT in its operations was identified. Negotiations with three parties of a single SC were performed, and confirmation for research participation was received from all three entities. The SC roles of the entities that were willing to participate were: first-tier supplier; transporter (3PL); and retailer. Full confidentiality was assured to all SC entities as a condition of their research participation.

The data collected from the three entities, operating in consecutive tiers in the same SC, was aimed at answering RQ1; thus, a qualitative approach was chosen. The semi-structured interview format was selected for data collection, as this was considered by the authors to be the most appropriate method for in-depth information collection regarding each SC participant's perceptions. The topics for the interview sessions were built based on a systematic literature review from extant literature in the field (Tokkozhina et al. 2022). Prior to the interview sessions, the topics that might be covered were sent to each participant (see Appendix). A one-to-one interview session with one representative from each of the three entities was scheduled based on the availability of the interviewee. The positions of the interviewed representatives were as follows: (1) first-tier supplier representative – quality control manager; (2) 3PL representative – manager of innovations and projects; and (3) retailer representative – supply chain director. All interviews were

conducted in English and were recorded for later verbatim transcription purposes upon the agreement of each participant. A total of three interviews were conducted via Zoom between December 2021 and January 2022, with an average duration of 40 min. Data treatment and analysis took place between February 2022 and April 2022, the qualitative content analysis software MAXQDA Analytics Pro 2022 was used for coding purposes. A visit to the supplier's site was also made to ensure familiarity with the operations and daily procedures regarding the BCT pilot.

The quantitative part of the research was administered to consumers via an online questionnaire sent to an initial convenience sample, and participants were requested to voluntarily share the questionnaire, i.e. using a snowballing technique, to ensure a higher response rate. The online questionnaire was built on the Qualtrics platform, with the questionnaire available in two languages: Portuguese (European) and English. Survey preparation took place between March 2022 and May 2022. The survey was first available online in May 2022 and the data collection took place between May 2022 and July 2022. The questionnaire comprised two main parts: multiple-choice sample characteristics identification (Table 1); and questions regarding interest in products' traceability information availability and purchasing decision variables [measured on a seven-point Likert scale (1 = "Not interested/Negative impact" to 7 = "Very interested/Positive impact")]. The inclusion criteria for participants were that they were at least 18 years old and had purchased fish products in Portugal (both continental and islands) at least once in the last six months. As the case study involved a Portuguese SC for frozen fish products, in which the retail chain was involved, it was necessary to identify the customers of this specific retail chain. Therefore, one of the criteria was that participants had bought fish from stores of the commercial brand that were part of the pilot study. As the SC explored had to remain confidential for research purposes, participants were given a list of Portuguese retail chains and asked to identify the one they used most often. Afterward, the fully completed questionnaires, which indicated a retail chain of interest were retrieved and used as a

Table 1 Description of Sample Characteristics (n = 112)

Gender	Female	56.3%
	Male	43.7%
	Non-binary	0%
	Prefer not to say	0%
Age	18 to 29 years old	37.5%
	30 to 39 years old	23.2%
	40 to 49 years old	17%
	50 to 59 years old	14.3%
	60 to 69 years old	4.5%
	70 to 79 years old	1.8%
	80 or above years old	1.8%
Education level	Primary school (4 years of school)	0.9%
	General secondary school (6 years of school)	8%
	General secondary school (9 years of school)	16.1%
	General high school (12 years of school) or technological specialization course	20.6%
	Bachelor's degree	32.1%
	Master's degree	24.1%
	Doctoral degree	14.3%
Purchasing behavior of fresh or frozen fish products in proportion	100% fresh fish	8.9%
	About 75% fresh fish and 25% frozen fish	28.6%
	About 50% fresh fish and 50% frozen fish	25.9%
	About 25% fresh fish and 75% frozen fish	25%
	100% frozen fish	11.6%
Number of family members who are considered when buying fish products	1–2 persons	59.8%
	3–4 persons	32.1%
	5–6 persons	8%
	7 or above	0%
Expenses on fish products per month	0 to 19.99 euros per month	31.3%
	20 to 39.99 euros per month	28.6%
	40 to 59.99 euros per month	25%
	60 to 79.99 euros per month	9.8%
	80 to 99.99 euros per month	1.8%
	100 euros or above	3.6%

sample for further data analysis. Owing to the convenience sample adopted, participants tended to be younger and more educated, which characterizes the tendency of future populations, as well as highlights the fact that younger consumers are more open to using novel technologies throughout the shopping experience. As the participants represented a younger population, the most common family size considered when buying fish products was one to two persons, which might explain the fact that 31.3% of participants only spent up to 19.99 euros on fish products per month (Table 1). Data analysis was further performed using IBM SPSS Statistics (version 27) software.

4 Findings

This section is divided into two parts, reflecting both the sample and data-collection method and this study's RQs. Section 4.1 explores how the motivation for BCT adoption and the willingness to share information differed throughout the MTSC studied, using a qualitative approach involving interviews with multiple tiers in one SC. Section 4.2 presents the findings for the quantitative research conducted among customers of a Portuguese retail chain to ascertain whether the potential information availability for frozen fish products added value for the final consumers.

4.1 Blockchain adoption process in a Multi-Tier Supply Chain (MTSC)

As this study explores one SC with multiple tiers, first, clarification was sought regarding the reason for the BCT pilot for SCM activities. All of the findings in this subsection are considered from the separate viewpoints of the different tiers: supplier; transporter; and retailer. The study showed that the overarching goal of the BCT pilot evolved from upstream to downstream in the SC. In this pilot, the supplier side perceived the reason for adoption as twofold: "*The main goal was to increase capacity and the speed of searching where the products are, when they are already at the retailing points … the second goal was trust towards the product: where was the fish caught before getting to the plate? This was the main objective.*" The retailer side further explained: "*We started the pilot to try to solve the traceability issues of a long supply chain.*" The view expressed by the middle tier of the SC (3PL) was as follows: "*We work with very big companies, and we like to be involved in such innovative projects. We know that our clients are participating [in a BCT pilot], and we are in the middle of the supply chain, so if they need us, we join up all the different parts: our needs are our client's needs and that is why we participate.*" Since the SC studied is the food industry, specifically frozen fish product distribution, there are some industry specifics that justify the need for novel traceability technologies. As mentioned by the participants, the food industry is complex as it has a lot of different requirements, and BCT can help guarantee trust in the product: "*… it is very important to know the quality of the product, because it is what people consume, so it is important for the whole chain.*"

Besides trust improvement towards the product, one of the positive outcomes of extensive information availability is compliance with sustainability concerns. The 3PL participant explained: "*… [with BCT] we prevent some things – if you have any problems with a product, you prevent this by not sending it to market, which guarantees sustainability.*" The retailer also saw another value-adding factor for a final consumer besides quick product recall: "*If the customer is sensitive and does not want to use products that were not extracted in the most eco-friendly way, having information in your hands really adds value. The customer knows everything that can be known about this product; that is a real value-adding factor.*"

It is important to mention that, before the BCT pilot, the participants of the study had already been functioning in the same SC for some years and had well-established long-term relationships with each other. It was clear from the interviews that trust in a product was one of the central pillars of the pilot, but the question remains as to whether BCT by itself is enough to provide such trust. The perspective of a downstream tier player is key to answering such a question as, at the retail points, products are received after they have already changed ownership several times across different SC players. When asked whether BCT removes the need for trust between partners, the retailer explained: "*In a blockchain, information will be secure, no one will touch it, but if we have some idea that partner is not fully trustworthy, we will doubt the quality of the information.*" Regarding the upper tier of the SC, the supplier explained that trust is born from information sharing: "*Trust is a requirement [for information] that partners want to know.*"

One of the main challenges and differences in this multi-tier BCT adoption case is the negotiation of information sharing requirements, namely which type of previously private information should be shared with partners. Downstream tiers wanted to see as much information about the product as possible: "*From the retailer point of view, it is the same as the client – we want to know where the product comes from … you need to force the supplier to provide the correct information because there can be a lot of information missing. Regarding the blockchain pilot, we also found, from the perspective of a food retailer, that we usually did not have the information not because we lacked the proper technology to trace it, but because the information was not provided.*" The upper tier did understand the possible need

for extensive information sharing: "*Blockchain has the capacity to share information; now we need to know what we can share with stakeholders. Because, for our clients, there should be as much 'suppliers' information' as possible. For example, if we see things from the perspective of a client that buys a product in a shop, we should not share so much information, and we need to restrict it. This is what we need to agree upon – what do we restrict and what do we not restrict.*" The BCT adoption pilot actually revealed the real issue for the SC; according to the retailer: "*The actual problem to solve is the lack of information, not a better way to address and share it.*" What is noteworthy is the fact that the supplier was open to possible negotiations regarding the information type that needs to be shared with other SC players: "*In this pilot, for example, we do not share the prices at which we buy from our own suppliers; it is only information about the product. But it could be.*"

There is one more challenge regarding information that was detected by the SC players, namely the quality of the information input into the BCT. BCT provides easier and more efficient access to information, but in cases where the records are inaccurate or contain errors, an immutable ledger entails extra work for the error extraction, as the information is tied in blocks and forms a sequence. The retailer side shared its BCT journey observations as follows: "*Our finding was that blockchain is a kind of garbage-in, garbage-out process. If you fail to record information correctly, you will have garbage going in and coming out. Blockchain is a 'safer and faster car' for information to move along the chain, but does not ensure the quality or the reliability of the information.*" The middle and upper tiers of the SC were aware of the "cost of mistakes" regarding erroneous information being input and took this very seriously, developing a long-term improvement plan; according to the 3PL respondent: "*Internally, we will have to provide more training for our operators so that they understand the impact of incorrect information … that part is our responsibility, and we have to be very careful and very responsible with that.*" The upper tier player's feedback concerned the time-consuming nature of the process regarding inputting data into the BCT system that was created for the pilot, which also signifies how demanding BCT is regarding the accuracy of the information. Everything needs to be double-checked before entering it into an immutable sequence of information blocks. "*In this case, we have a little more work: collecting data, putting it on platform – it is time-consuming … The investment is more of time, because it runs in parallel with other traditional systems – our partners also shared that they feel it is a more time-consuming process.*"

The decentralized nature of BCT ledgers also highlights an interesting point for discussion. From the perspective of the 3PL tier, whose main goal is to meet customer service expectations, BCT brings both advantages and risks. One advantage that 3PL sees is the efficiency in information access for their customers: without BCT, all data about previous transactions/articles have to be made manually and sent to the client upon request, but BCT eliminates this need. The retailer fully supported this view, describing the experience with the decentralized ledger as follows: "*We are much faster at accessing the information … for a long supply chain, information access sometimes requires looking through 10–12 emails.*" However, the 3PL side also sees potential risk in keeping information without a central entity: "*If the ledger has a problem, all the supply chain will have a problem. Let's imagine that someone attacks the blockchain; it means everyone will be blind with no information. But, for example, in a centralized environment, if one partner has a problem, another entity still has the information.*"

One of the most important improvements that all SC tiers were able to witness in this pilot was the speed of information access. When considering food SCs, the time required to access specific information is crucial, especially for SCs involved in perishable goods that may potentially harm the health of consumers if not stored under the required conditions. Here, BCT brings an irreplaceable innovation for all tiers; according to the retailer: "*If we have some problem with food, I can raise the alarm and the shops can recall the product. It is amazing – it is a step that can be important for all partners involved, all partners agree that this is a great benefit that we obtained. We can also achieve this through other technology, but the information will take two to three days – blockchain is much faster.*" The 3PL respondent also saw the achievement of the main goal for a food SC: "*We achieved the goal of the pilot – reducing the lead time between the recall and getting information on that recall. With blockchain, in 10 minutes you have the information – that is the biggest advantage of the pilot.*" For the retailer tier, which is closer to downstream and the final consumer, the speed of information retrieval is essential to ensure the safety of products: "*That is probably one of the biggest issues from the retailer point of view – to get information quickly, to know exactly to which stores the product was sent, because most of the time not only legal issues, but also some health issues for clients, may arise, so it is important for us.*"

4.2 The views of final consumers on information availability for Fish Products

The natural purchasing behavior of consumers towards fish products (whether fresh or frozen) was identified among the sample, which also reduced the chances of bias among the questionnaire participants. As can be seen from Tables 1 and

79.5% of consumers usually purchased a mixture both of fresh and frozen fish products; moreover, consumers exclusively buying fresh fish were in the minority compared to those exclusively buying frozen fish products (8.9% and 11.6%, respectively). The habit of buying both fresh and frozen fish can be explained by the geographical proximity of the country to the ocean, which provides consumers with a wide array of fish product options.

To identify interest in using novel technologies for product traceability and its potential impact on purchasing decisions, the relationship between the level of interest in traceable information and the level of willingness to purchase fish products with traceable information available was analyzed.

A p-value < 0.05 was considered significant. To ascertain whether there is any relationship between the sample characteristics in Table 1 and willingness to make a purchase decision, a regression analysis was run with the level of interest in traceable information as the dependent variable. Regression analysis did not show any statistically significant relationship between the sample characteristics from Table 1 and their impact on purchasing decisions with significance factors ranging from 0.150 to 0.444. Further, to test the relationship between interest in products' traceability information availability and purchasing decisions, a regression analysis was run with the level of interest in traceable information as the independent variable. The result showed significance, with a p-value of 0.000. To check the strength and direction of the linear relationships between two variables, a Pearson correlation test was run, again with the level of interest in traceable information as the independent variable. This resulted in a Pearson correlation significance of 0.522** with a two-tailed significance of 0.000 (i.e. $p < 0.05$), signifying that the correlation is positive, strong, and significant. This shows that none of the sample's descriptive factors from Table 1, such as age, gender, education level, etc., have an impact on purchasing decisions for products with traceability information availability. However, as can be seen in Fig. 1, interest in having information about the origins of the fish product(s) positively impacts further purchasing decisions for such products with traceability information availability. Interestingly, according to Fig. 1, even for those consumers that are not interested in having available information about products' origins, if this information is already available, it has a positive impact on their purchasing decisions. This means that the novelty of the features of the fish product(s) drives the interest of consumers, creating more a favorable environment for product purchasing. Moreover, based on the results obtained, it is possible to assume that consumers' education level and age have no impact, meaning that any consumer will experience a positive impact on purchasing decisions when there is traceability information availability for the fish product(s).

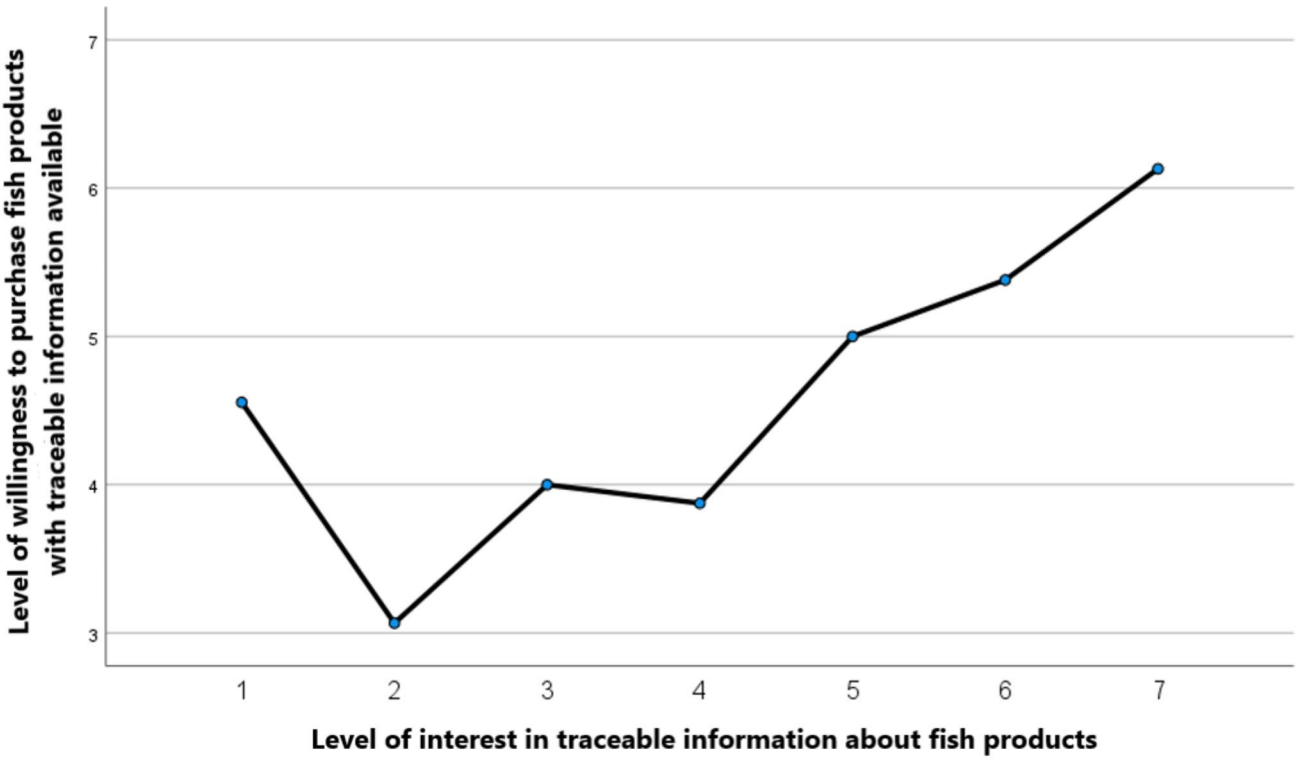

Fig. 1 Relationship between the level of interest in traceable information and the level of purchase willingness of traceable fish products

5 Discussion

The findings of the qualitative research highlighted the feedback and views of different tiers in a single SC. First, the intentions and expectations behind the project were found. The general intention of the pilot was to generate more trust in the products through the use of traceability technology. Here, one can see how the supplier recognizes the benefits of quick product detection when products are out of their control and are already at the retail points. Thus, BCT was piloted as a technology that promises to bring fast information extraction. Moreover, the trust and traceability of the product itself are crucial both for upstream and downstream players in the studied pilot, which signifies the joint goal of achieving competitive advantage through innovation and transparency. Based on the findings of the pilot, a multiple-tier adoption can only happen when all parties agree to participate; otherwise, BCT would not be able to deliver its main innovativeness (information traceability), as it would be incomplete without the middle tiers of the SC. When theorizing collaboration in multi-tier SCs, Vlachos and Dyra (2020) proposed that mid-chain parties, namely 3PLs, become SC integrators, with retailers playing a leading role in setting key performance indicators, and suppliers moving towards dependency upon 3PLs' structural and relational embeddedness. However, in the case of the BCT pilot studied, it can be seen that both upstream and downstream players depend on the 3PL's participation and collaboration in the adoption process. Mid-tier participation is shown to be a crucial component, because otherwise there would be a discontinuity of information in the chain, leading to the traceability function losing its value as there would be clear gaps in the ownership of data. Thus, we suggest that a pilot preparation should start by bringing together all consecutive tiers whose data is essential for continuous information tracking throughout the SC. BCT will lose its innovation and value if the information inputs have gaps throughout the product's movement history.

As well as generating trust in the final consumer towards fish products, the pilot showed that BCT can also simultaneously address sustainability concerns. According to Aschemann-Witzel et al. (2019), consumers recognize food ingredients according to a "known-natural-good," which therefore impacts their purchasing decisions. As indicated by participants in this study, BCT's tamper-proof records enable transparency for final consumers in terms of the data input concerning food additives or the capture/storage conditions of fish, which allows consumers the freedom to make accurate choices and can prevent potential health problems. Bai and Sarkis (2020) argued that those businesses seeking to invest in BCT solutions need to set up supporting performance measurement systems for transparency and sustainability goals. In general, the use of disruptive technologies in an industry context enables less resource usage, thus reducing the need for excessive materials (Khan et al. 2022c). However, the findings from the pilot show that sustainability achievement is rather a result of the traceability features of BCT, which come naturally, as the backward information verification function becomes available for final consumers. This thus represents a win–win situation for all SC tiers, as upstream players acquire an innovation in the ability to track goods after they move forwards in the SC, while downstream players gain in terms of the health and safety assurance of products and transparent information about the initial stages of products' processing.

In the extant literature, blockchain is considered a trust-enabling technology (Centobelli et al. 2021) that can build trust among participants (Li et al. 2021). However, the present paper's findings reveal that, even though participants are seeking through BCT an extra layer of trust towards the product for final consumers, BCT does not build trust among participants. This can be explained by the fact that an unknown or untrustworthy SC entity will raise doubts regarding the veracity of the data input in the ledger. In the present study, the SC entities had been partnering for years before BCT adoption, which made them feel comfortable investing and piloting the technology together. As one of the most innovative BCT features is the immutability of data, having the correct information for each transaction is crucial, as otherwise, the retrieval of correct inputs will be time-consuming, and thus not acceptable for a sensitive SC such as perishable food distribution. This finding can be explained by the fact that, at this nascent stage of BCT integration for SC practices, all entities are in the same position and fear the "unknown" that the introduction of this new technology entails. Therefore, unless BCT clearly shows itself to be an optimal and necessary application, such pilots are easier to start among established SC players, where trust between the entities themselves has already been established.

The next finding reveals one of the central challenges that all players in the pilot recognized. As discussed above, the general intention of the pilot was to generate more trust for final consumers through the application of traceability technology. Moreover, the specific SC explored had already been partnering for years, which made the adoption smooth, as extra trust-building between entities was not required. However, even with trustworthy partners, a challenge remains in terms of extensive information sharing from upstream to downstream. What was revealed in the findings of the study is the discrepancy between information demand and the willingness to share it. It is expected that downstream SC players that are located closer to final consumers wish to see more private information from upper-tier players, as this information might bring more transparency

and traceability to the product itself. The extant literature usually suggests that first-tier suppliers are hesitant when information on transactions or relationships with their suppliers needs to be exposed (Vyas et al. 2019). However, in the present paper's findings, the upper tiers recognized the value of extensive information availability about the product and were open to the negotiation of specific information provision based on the needs of downstream players. This might be explained by the overall strong partnering relationships between players in the explored pilot, where all partners recognized the importance of successful product distribution for the positive consumption experience of final customers. The key question, therefore, concerns what kind of information should be shared and whether it would bring value to the end-consumers. Accordingly, based on the findings, we suggest negotiating and documenting the type of information that needs to be captured in the blockchain for a specific pilot. This will not only result in greater transparency but will also likely lead to greater satisfaction with the BCT adoption for all players, as it would bring novelty to the product information availability.

Another challenge detected in this SC relates to the information quality input. Wan et al. (2020) claimed that BCT-enabled information-sharing deployment within a SC ensures that all participants can have access to verified information, thus enhancing collaborative partnerships. However, the piloting SC revealed a "downside" to this information sharing, namely that attempting to insert perfectly correct, error-free information into the immutable ledger is a time-consuming process, as it requires double-checking. In the case of information correctness, BCT does not add the extra value, it only provides the tamper-proof guarantee and the immutability of the records, but it cannot verify whether the records are correct. Thus, in this context, the immutability feature represents more of a challenge than an advantage, as any future corrections to the information in the BCT network, although possible, are extremely difficult and resource-consuming. The nature of the BCT ledger requires altering information in every previous block, as all of them are connected with the hash of the previous transaction input. One can conclude, as highlighted by one of the interviewed entities, that there is a need for further training for employees. Training and time may be required to gain confidence in using BCT and putting the information into it without hesitation, which once again highlights the nascent stage of BCT adoption in practice. For broader adoption in the future, Powell et al. (2022) also suggested integrating BCT with (IoT) oracles for event tracking in SCs and product provenance assurance for data integrity.

The duality of storing information in a decentralized manner represents another important finding worthy of discussion. According to the study participants, the distributed nature of BCT records represents a clear novelty in terms of independent information access, especially for middle and downstream tiers, as they usually need to see specific records about previous or ongoing stages of product distribution. Manual information search, extraction, and sharing are undoubtedly more time-consuming; thus, BCT can address this constraint, providing more efficiency in information retrieval. However, the decentralized environment creates risks that were recognized by participants: in the case of an attack or technical issue, a cloud-based technology might not be safe, as all participants would lose visibility and access simultaneously. To mitigate such concerns, Wu et al. (2017) suggested that BCT, although primarily designed for a distributed architecture, might also be executed in a centralized manner. However, we do not suggest that pilots adopt BCT in a centralized manner, because this eliminates the main novelty of the technology, forcing it to become just a database, when it was not designed to be such, furthermore requiring extra investment for the adoption process. Instead, to gain confidence in BCT and fully comprehend the functionality behind it, pioneers should start pilots in a permissioned environment, where only participants that have a pair of digital keys have access to the visibility of transactions and further record-making. This approach will reduce the possibilities of attack, as all the participants who have access will be chosen by a consortium of SC members involved in the pilot.

One of the most visible improvements that were revealed through interviews was the information access acceleration across the SC. Bumblauskas et al. (2019) discussed the traceability and transparency of BCT-based food SCs, which enables efficiency increases and the reduction of risks related to food recalls. BCT use for perishable food products may also bring cost reductions, as instead of recalling entire product series, retailers can identify the specific batch(es) affected and trace to which retail point they have been distributed (Kayikci et al. 2021). The present paper's findings also support this argument, showing the value of quick information access for perishable product distribution. The findings also suggest that it is not so much the transparency and traceability features of BCT that enable quick recall, but rather the distributed nature of the digital ledger. When SC participants have absolutely equal access to the same immutable records, one entity can detect a threat and can alert other participants, who will be able to quickly access and check the record details, enabling them to quickly take decisions regarding further actions for potentially harmful products.

Treiblmaier and Garaus (2022) applied signaling theory and tested a model that explores the influence of traceability systems on perceived product quality, resulting in an increase in consumers' purchases through BCT-enabled traceability

labeling. Specifically, unfamiliar product brands were perceived as higher quality when a BCT-enabled traceability label was on the package. The present paper's quantitative approach, however, differs as it was based on a supermarket chain often used by consumers. Thus, the present paper's findings enrich the extant literature, showing that, without a specific connection to the brand familiarity of a product itself, consumers' purchasing intentions for fish products in a popular supermarket can be positively impacted by having information available on the product's origins and processing stages. Moreover, BCT was deliberately not mentioned in the consumer questionnaire in order not to create bias over the recent "hype" concerning this technology, thus revealing the true value and impact of traceability information availability without binding it to a specific disruptive solution. Furthermore, no significant difference in purchasing decisions was found based on the product type that consumers usually buy: consumers were more likely to purchase both fresh and frozen fish products when traceability/origin information was available. Therefore, when considering an end-to-end multi-tier SC, it can be concluded that efforts towards traceability information coming from the upper tiers of the SC truly drive final consumers' increased purchasing decisions, which is also in line with the retailer's motivation to bring value to the final consumers.

6 Conclusions and future directions

A multi-tier SC is characterized by a complex environment of relationships between different elements; therefore, any attempt to bring innovation through novel technologies needs to be well explored and justified in terms of the value that is expected from the technology adoption. This study aimed to investigate the potential existence of differences in motivations across multiple tiers of SC participants regarding BCT adoption, as well as views on the contributions and expectations regarding traceability information availability. In the case explored, it was evident that each player in the MTSC was mostly interested in meeting the expectations of its first-tier customer, with the overall aim of satisfying the final consumer. The case explored deals with frozen fish, a sensitive and perishable product, which makes this satisfaction request even more relevant. This study enriches the extant literature by examining four tiers of a single SC (supplier, 3PL, retailer, and final consumers of a supply chain) regarding the value and importance of the availability of traceability information.

This study shows that the availability of traceability information for fish product origins has a positive impact on consumers' purchasing decisions, driving more sales of traceable products and bringing more value to all SC tiers. Based on the quantitative results from the final consumers, it can be concluded that this traceability information about fish products is valuable and that it is driving greater interest in purchasing. BCT was not mentioned to the final consumers as a technology of interest to avoid bias, therefore it was possible to analyze the real value of traceability information.

All four tiers of SC participants investigated in this study showed to pursue a common main goal of having the possibility to trace the information about fish products. However, there are some differences in motivations among the four tiers (supplier, transporter, retailer and final consumer) that need to be highlighted:

- The supplier is mostly focused on traceability to increase the trust towards the product for both retailers and final consumers;
- The transporter is realizing the crucial position that it occupies in the SC, thus participation is motivated by the willingness to "not break" the chain of traceable information, as the transportation provider is providing a service between two other tiers in the SC;
- The retailer is motivated by the ability to trace the information throughout the product movement in the SC, aiming to assure the safety of the fish products that are put up for sale in retailing points;
- The final consumers, even in cases when initially were not motivated to receive traceable information about fish products, show a higher intention to purchase fish products if there is the possibility to have access to the information that allows tracing the origin of the product.

As seen from the present study, endeavors towards providing traceability information for frozen fish products coming from multiple SC stakeholders result in final consumers' greater interest in purchasing novel products with extensive information availability regarding the origins and processing stages of the products. To the best of the authors' knowledge, this study is the first attempt in the academic literature to bring together four different tiers of a single SC involved in the adoption of BCT for frozen fish products, as well as using a mixed methodology to obtain more accurate results. This study contributes both to academia, by revealing MTSC elements' different views and motivations towards BCT adoption and information sharing, as well as to the managerial world, by providing a holistic overview of an example of a real BCT adoption case for a perishable food SC, thus allowing businesses the value of traceability solutions in their SCs. By applying a mixed method approach, this study is contributing to current SCM academic literature by exploring different tiers of a single SC using various methods for bias reduction of participants, leaving an

opportunity for future research to apply a similar approach for data collection and analysis.

This study is limited to the specifics of the products involved in distribution. As perishable, non-basic commodities, fish products represent a specific industry, and such products might be tampered with or experience inappropriate storage and transportation conditions, leading to possible health impacts on consumers, which justifies the need for traceability. However, this study can be used as an example for almost all perishable food product SC, as the goal of providing safety assurance to final consumers is similar in their respective SCs. Another issue that could be seen as limiting the results of this study is that it was conducted within a Portuguese SC, and a retail chain with consumers representing the Portuguese market and with specific cultural views. The number of participants of the qualitative part of the study was limited to three individuals representing organizations involved in a single SC, however, this limitation is explained by the fact that these three individuals are the ones directly and deeply involved in the BCT pilot. Moreover, changing from qualitative research to quantitative one in the final tier of the SC could be seen as a limitation, however, interviewing final consumers, although being able to provide richer data, would be limited by the number of respondents and therefore stress the cultural perspectives of the respondents. Thus, an online survey was applied to collect data among final consumers, which provided more convenience for respondents and allowed reaching a larger audience. In future studies, it would be interesting to examine MTSCs for other types of food products, which are not characterized by perishability and sensitivity to distribution conditions, and to understand whether the nature of the product influences the impact of traceability information availability on the purchase intention among consumers.

Appendix

Semi-structured interview guidelines by topics.

- Blockchain technology (BCT) pilot journey.
- Intentions behind the BCT pilot for supply chain management (SCM).
- Partners' involvement in the BCT pilot.
- Collaboration experience in the BCT pilot.
- Information sharing experience and concerns in BCT pilot.
- Impact of BCT in data security and transparency of records.
- Impact of BCT on product safety assurance and trust.
- Traceability of BCT-based networks and impact on sustainability concerns.
- BCT knowledge and awareness raise.

Acknowledgements This work was supported by EEA Grants Blue Growth Programme (Call #5), Project PT-INNOVATION-0069 – Fish-2Fork and Logistics Department of Molde University College.

Funding Open access funding provided by FCT|FCCN (b-on).

Conflict of interest The authors have no competing interests to declare that are relevant to the content of this article.

References

Agrawal TK, Kumar V, Pal R, Wang L, Chen Y (2021) Blockchain-based framework for supply chain traceability: a case example of textile and clothing industry. Comp & Ind Eng. https://doi.org/10.1016/j.cie.2021.107130. 154:107130

Aschemann-Witzel J, Varela P, Peschel AO (2019) Consumers' categorization of food ingredients: do consumers perceive them as 'clean label'producers expect? An exploration with projective mapping. Food Qual Pref 71:117–128. https://doi.org/10.1016/j.foodqual.2018.06.003

Aung MM, Chang YS (2014) Temperature management for the quality assurance of a perishable food supply chain. Food Contr 40(1):198–207. https://doi.org/10.1016/j.foodcont.2013.11.016

Baah C, Acquah ICK, Ofori D (2021) Exploring the influence of supply chain collaboration on supply chain visibility, stakeholder trust, environmental and financial performances: a partial least square approach. Benchmark Int J 29(1):172–193. https://doi.org/10.1108/BIJ-10-2020-0519

Bai C, Sarkis J (2020) A supply chain transparency and sustainability technology appraisal model for blockchain technology. Int J Prod Res 58(7):2142–2162. https://doi.org/10.1080/00207543.2019.1708989

Behl A, Jayawardena NS, Pereira V, Sampat B (2022) Assessing retailer readiness to use blockchain technology to improve supply chain performance. J Ent Inform Manag. https://doi.org/10.1108/JEIM-07-2022-0242

Bumblauskas D, Mann A, Dugan B, Rittmer J (2019) A blockchain use case in food distribution: do you know where your food has been? Int J Inf Man 52:102008. https://doi.org/10.1016/j.ijinfomgt.2019.09.004

Callinan C, Vega A, Clohessy T, Heaslip G (2022) Blockchain adoption factors, enablers, and barriers in fisheries supply chain: preliminary findings from a systematic literature review. J Brit Block Assoc 5(1):32437. https://doi.org/10.31585/jbba-5-1-(3)2022

Cao BB, Zhu MF, Tian Q (2022) Optimal operation policies in a cross-regional Fresh Product Supply Chain with Regional Government

Subsidy Heterogeneity to Blockchain-Driven Traceability. Math 10(23):4592. https://doi.org/10.3390/math10234592
Casino F, Kanakaris V, Dasaklis TK, Moschuris S, Stachtiaris S, Pagoni M, Rachaniotis NP (2021) Blockchain-based food supply chain traceability: a case study in the dairy sector. Int J Prod Res 59(19):5758–5770. https://doi.org/10.1080/00207543.2020.1789238
Centobelli P, Cerchione R, Del Vecchio P, Oropallo E, Secundo G (2021) Blockchain technology for bridging trust, traceability and transparency in circular supply chain. Inf & Manag 103508. https://doi.org/10.1016/j.im.2021.103508
Cimini C, Boffelli A, Lagorio A, Kalchschmidt M, Pinto R (2020) How do industry 4.0 technologies influence organisational change? An empirical analysis of italian SMEs. https://doi.org/10.1108/JMTM-04-2019-0135/. J Man Tech Manag
Cocco L, Tonelli R, Marchesi M (2021) Blockchain and Self Sovereign Identity to Support Quality in the Food Supply Chain. Fut Int 13(12):301. https://doi.org/10.3390/fi13120301
Dutta PK, Mitra S (2021) Application of agricultural drones and IoT to understand food supply chain during post COVID-19. In:Agricultural Informatics: Automation Using the IoT and Machine Learning, pp 67–87. https://doi.org/10.1002/9781119769231.ch4
Farshidi S, Jansen S, España S, Verkleij J (2020) Decision support for blockchain platform selection: three industry case studies. IEEE Trans Eng Manag 67(4):1109–1128. https://doi.org/10.1109/TEM.2019.2956897
Fong VHI, Hong JFL, Wong IA (2021) The evolution of triadic relationships in a tourism supply chain through coopetition. Tour Manag 84:104274. https://doi.org/10.1016/j.tourman.2020.104274
Geneiatakis D, Soupionis Y, Steri G, Kounelis I, Neisse R, Nai-Fovino I (2020) Blockchain performance analysis for supporting cross-border E-government services. IEEE Tran Eng Manag 67(4):1310–1322. https://doi.org/10.1109/TEM.2020.2979325
Gray B, Purdy J (2018) Collaborating for our future: Multistakeholder partnerships for solving complex problems. Oxford University Press
Horvath L (2001) Collaboration: the key to value creation in supply chain management. Sup Ch Manag Int J 6(5):205–207. https://doi.org/10.1108/EUM0000000006039
Howson P (2020) Building trust and equity in marine conservation and fisheries supply chain management with blockchain. Mar Policy 115:103873. https://doi.org/10.1016/j.marpol.2020.103873
Huang Y, Han W, Macbeth DK (2020) The complexity of collaboration in supply chain networks. Sup Ch Manag Int 25(3):393–410. https://doi.org/10.1108/SCM-11-2018-0382
Johnson A, McCurdy D, Schechter D, Loch K (2020) Hot or Cold… How Ready are Third Party Logistics Cold Storage Companies to Implement Blockchain?. In:53 Hawaii Int Conf Sys Sci, Maui, Hawaii, 2020, pp.5308–5317
Juma H, Shaalan K, Kamel I (2019) A Survey on using Blockchain in Trade Supply Chain Solutions. IEEE Acc 7:184115–184132. https://doi.org/10.1109/ACCESS.2019.2960542
Kafeel H, Kumar V, Duong L (2023) Blockchain in Supply Chain Management: a synthesis of barriers and enablers for managers. Int J Math Eng Manag Sci. https://doi.org/10.33889/IJMEMS.2023.8.1.002
Kamble SS, Gunasekaran A, Sharma R (2019a) Modeling the blockchain enabled traceability in agriculture supply chain. Int J Inf Man 52:101967. https://doi.org/10.1016/j.ijinfomgt.2019.05.023
Kamble S, Gunasekaran A, Arha H (2019b) Understanding the blockchain technology adoption in supply chains – indian context. Int J Prod Res 57(7):2009–2033. https://doi.org/10.1080/00207543.2018.1518610
Kamble SS, Gunasekaran A, Kumar V, Belhadi A, Foropon C (2021) A machine learning based Approach for Predicting Blockchain Adoption in Supply Chain. Tech Forecast Soc Change 163:120465. https://doi.org/10.1016/j.techfore.2020.120465
Kayikci Y, Usar DD, Aylak BL (2021) Using blockchain technology to drive operational excellence in perishable food supply chains during outbreaks. Int J Log Manag. https://doi.org/10.1108/IJLM-01-2021-0027
Khan SAR, Yu Z (2021) A systematic literature review: blockchain technology and organizational theories in the perspective of supply chain management. In: Journal of Physics: Conference Series, IOP Publishing, 1910(1), p. 012011
Khan SAR, Zkik K, Belhadi A, Kamble SS (2021a) Evaluating barriers and solutions for social sustainability adoption in multi-tier supply chains. Int J Prod Res 59(11):3378–3397. https://doi.org/10.1080/00207543.2021.1876271
Khan SAR, Godil DI, Jabbour CJC, Shujaat S, Razzaq A, Yu Z (2021b) Green data analytics, blockchain technology for sustainable development, and sustainable supply chain practices: evidence from small and medium enterprises. Ann Oper Res. https://doi.org/10.1007/s10479-021-04275-x
Khan SAR, Razzaq A, Yu Z, Miller S (2021c) Industry 4.0 and circular economy practices: a new era business strategies for environmental sustainability. Bus Strat Env 30(8):4001–4014. https://doi.org/10.1002/bse.2853
Khan SAR, Yu Z, Sarwat S, Godil DI, Amin S, Shujaat S (2022a) The role of block chain technology in circular economy practices to improve organisational performance. Int J Log Res App 25(4–5):605–622. https://doi.org/10.1080/13675567.2021.1872512
Khan SAR, Piprani AZ, Yu Z (2022b) Supply chain analytics and post-pandemic performance: mediating role of triple-A supply chain strategies. Int J Emer Mar. https://doi.org/10.1108/IJOEM-11-2021-1744
Khan SAR, Piprani AZ, Yu Z (2022c) Digital technology and circular economy practices: future of supply chains. Oper Manag Res 15(3–4):676–688. https://doi.org/10.1007/s12063-021-00247-3
Kittipanya-Ngam P, Tan KH (2020) A framework for food supply chain digitalization: lessons from Thailand. Prod Plan Contr 31(2–3):158–172. https://doi.org/10.1080/09537287.2019.1631462
Kouhizadeh M, Saberi S, Sarkis J (2020) Blockchain technology and the sustainable supply chain: theoretically exploring adoption barriers. Int J Prod Econ 231:107831. https://doi.org/10.1016/j.ijpe.2020.107831
Kramer MP, Bitsch L, Hanf JH (2021) The impact of instrumental stakeholder management on blockchain technology adoption behavior in agri-food supply chains. J Risk Fin Manag 14(12):598. https://doi.org/10.3390/jrfm14120598
Li K, Lee JY, Gharehgozli A (2021) Blockchain in food supply chains: a literature review and synthesis analysis of platforms, benefits and challenges. Int J Prod Res. https://doi.org/10.1080/00207543.2021.1970849
Liu Z, Sampaio P, Pishchulov G, Mehandjiev N, Cisneros-Cabrera S, Schirrmann A, Jiru F, Bnouhanna N (2022a) The architectural design and implementation of a digital platform for industry 4.0 SME collaboration. Comp Ind 138:103623. https://doi.org/1016/j.compind.2022a.103623
Liu W, Liu X, Shi X, Hou J, Shi V, Dong J (2022b) Collaborative adoption of blockchain technology: a supply chain contract perspective. Front Eng Manag. https://doi.org/10.1007/s42524-022-0239-8
Madumidha S, Ranjani PS, Varsinee SS, Sundari PS (2019) Transparency and traceability: In food supply chain system using blockchain technology with internet of things. In 2019 3 Int Conf Trends Elect Inform (ICOEI) 983–987
Menon S, Jain K (2021) Blockchain Technology for transparency in Agri-Food Supply Chain: use cases, Limitations, and future directions. IEEE Tran Eng Manag. https://doi.org/10.1109/TEM.2021.3110903

Mesic Ž, Molnár A, Cerjak M (2018) Assessment of traditional food supply chain performance using triadic approach: the role of relationships quality. Supp Ch Manag 23(5):396–411. https://doi.org/10.1108/SCM-10-2017-0336

Najjar M, Alsurakji IH, El-Qanni A, Nour AI (2022) The role of blockchain technology in the integration of sustainability practices across multi-tier supply networks: implications and potential complexities. J Sust Fin Invest. https://doi.org/10.1080/20430795.2022.2030663

Nguyen TT, Li D (2022) Towards Safer Global Food Supply Chains: a comparative analysis of Regulatory requirements. Springer Nature

Ojha D, Sahin F, Shockley J, Sridharan SV (2019) Is there a performance tradeoff in managing order fulfillment and the bullwhip effect in supply chains? The role of information sharing and information type. Int J Prod Econ 208:529–543. https://doi.org/10.1016/j.ijpe.2018.12.021

Pal A, Kant K (2018) IoT-based sensing and communications infrastructure for the fresh food supply chain. Comp 51(2):76–80. https://doi.org/10.1109/MC.2018.1451665

Perera HN, Hurley J, Fahimnia B, Reisi M (2019) The human factor in supply chain forecasting: a systematic review. Eur J Oper Res 274(2):574–600. https://doi.org/10.1016/j.ejor.2018.10.028

Powell W, Foth M, Cao S, Natanelov V (2022) Garbage in garbage out: the precarious link between IoT and blockchain in food supply chains. J Ind Inform Integ 25:100261. https://doi.org/10.1016/j.jii.2021.100261

Rejeb A (2018) Halal meat supply chain traceability based on HACCP, blockchain and internet of things. Acta Tech Jaur 11(1). SSRN: https://ssrn.com/abstract=3319432

Rejeb A, Rejeb K, Zailani S, Treiblmaier H, Hand KJ (2021a) Integrating the internet of things in the halal food supply chain: a systematic literature review and research agenda. Internet of Things 13:100361. https://doi.org/10.1016/j.iot.2021.100361

Rejeb A, Keogh JG, Simske SJ, Stafford T, Treiblmaier H (2021b) Potentials of blockchain technologies for supply chain collaboration: a conceptual framework. Int J Log Manag 32(3):973–994. https://doi.org/10.1108/IJLM-02-2020-0098

Saberi S, Kouhizadeh M, Sarkis J, Shen L (2019) Blockchain Technology and its Relationships to sustainable supply Chain Management. Int J Prod Res 57(7):2117–2135. https://doi.org/10.1080/00207543.2018.1533261

Sales-Vivó V, Gil-Saura I, Gallarza MG (2020) Value co-creation and satisfaction in B2B context: a triadic study in the furniture industry. Sust 13(1):152. https://doi.org/10.3390/su13010152

Saurabh S, Dey K (2021) Blockchain technology adoption, architecture, and sustainable agri-food supply chains. J Clean Prod 284:124731. https://doi.org/10.1016/j.jclepro.2020.124731

Siddiqui R, Azmat M, Ahmed S, Kummer S (2022) A hybrid demand forecasting model for greater forecasting accuracy: the case of the pharmaceutical industry. Sup Ch For: Int J 23(2):124–134. https://doi.org/10.1080/16258312.2021.1967081

Sternberg HS, Hofmann E, Roeck D (2021) The struggle is real: insights from a supply chain blockchain case. J Bus Log 42(1):71–87. https://doi.org/10.1111/jbl.12240

Stranieri S, Riccardi F, Meuwissen MPM, Soregaroli C (2020) Exploring the impact of blockchain on the performance of agri-food supply chains. Food Cont 119:107495. https://doi.org/10.1016/j.foodcont.2020.107495

Sumarliah E, Li T, Wang B, Khan SU, Khan SZ (2023) Blockchain technology adoption in halal traceability scheme of the food supply chain: evidence from indonesian firms. Int J Emerg Mar. https://doi.org/10.1108/IJOEM-05-2021-0678

Swierczek A (2020) Relational orientation of triadic supply chains with structural holes: an empirical comparison of rents derived from bridging the structural holes. Supp Ch Manag 25(5):565–583. https://doi.org/10.1108/SCM-10-2019-0382

Tian F (2017) A supply chain traceability system for food safety based on HACCP, blockchain & internet of things. IEEE 2017 int con serv sys ser Manag. Doalian, China, pp 1–6

Tliche Y, Taghipour A, Mahfod-Leroux J, Vosooghidizaji M (2023) Collaborative bullwhip effect-oriented bi-objective optimization for inference-based weighted moving average forecasting in decentralized supply chain. Int J Inf Sys Sup Ch Manag 16(1):1–37. https://doi.org/10.4018/IJISSCM.316168

Tokkozhina U, Martins AL, Ferreira JC (2020) Adopting Blockchain in Supply Chain–An Approach for a pilot. Intelligent Transport Systems, from Research and Development to the Market Uptake. Springer, Cham, pp 125–141. https://doi.org/10.1007/978-3-030-71454-3_8.

Tokkozhina U, Ferreira JC, Martins AL (2021) Wine traceability and Counterfeit reduction: Blockchain-Based application for a wine supply chain. Intelligent Transport Systems, from Research and Development to the Market Uptake. Springer, Cham., pp 59–70. https://doi.org/10.1007/978-3-030-97603-3_5.

Tokkozhina U, Martins AL, Ferreira JC (2022) Uncovering dimensions of the impact of blockchain technology in supply chain management. Oper Manag Res. https://doi.org/10.1007/s12063-022-00273-9

Treiblmaier H, Garaus M (2022) Using blockchain to signal quality in the food supply chain: the impact on consumer purchase intentions and the moderating effect of brand familiarity. Int J Inf Manag. https://doi.org/10.1016/j.ijinfomgt.2022.102514

Vlachos I, Dyra SC (2020) Theorizing coordination, collaboration and integration in multi-sourcing triads (B3B triads). Supp Ch Manag 25(3):285–300. https://doi.org/10.1108/SCM-01-2019-0006

Vyas N, Beije A, Krishnamachari B (2019) Blockchain and the supply chain: concepts, strategies and practical applications. Kogan Page Publishers, London, United Kingdom

Wan PK, Huang L, Holtskog H (2020) Blockchain-enabled information sharing within a supply chain: a systematic literature review. IEEE Acc 8:49645–49656. https://doi.org/10.1109/ACCESS.2020.2980142

Wang Y, Singgih M, Wang J, Rit M (2019) Making sense of blockchain technology: how will it transform supply chains? Int J Prod Econ 211:221–236. https://doi.org/10.1016/j.ijpe.2019.02.002

Wang B, Lin Z, Wang M, Wang F, Xiangli P, Li Z (2022) Applying blockchain technology to ensure compliance with sustainability standards in the PPE multi-tier supply chain. Int J Prod Res. https://doi.org/10.1080/00207543.2022.2025944

Wu H, Li Z, King B, ben Miled Z, Wassick J, Tazelaar J (2017) A distributed ledger for supply chain physical distribution visibility. Inform 8(4):137. https://doi.org/10.3390/info8040137

Yadav S, Luthra S, Garg D (2020) Internet of things (IoT) based coordination system in Agri-food supply chain: development of an efficient framework using DEMATEL-ISM. Oper Manag Res. https://doi.org/10.1007/s12063-020-00164-x

Yadlapalli A, Rahman S, Gopal P (2022) Blockchain technology implementation challenges in supply chains–evidence from the case studies of multi-stakeholders. Int J Log Manag 33(5):278–305. https://doi.org/10.1108/IJLM-02-2021-0086

Yerpude S, Sood K, Grima S (2022) Blockchain-Augmented Digital Supply Chain Management: a way to Sustainable Business. J Risk Fin Manag 16(1):7. https://doi.org/10.3390/jrfm16010007

Zavala Nacul H, Revoredo-Giha C (2022) Food safety and the informal milk supply chain in Kenya. Agri Food Sec. https://doi.org/10.1186/s40066-021-00349-y

Zheng Y, Xu Y, Qiu Z (2023) Blockchain Traceability Adoption in Agricultural Supply Chain Coordination: an evolutionary game analysis. Agricult 13(1):184. https://doi.org/10.3390/agriculture13010184

IBM Food Trust : A new era in the world's food supply https://www.ibm.com/blockchain/solutions/food-trust