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Leveraging the circular economy with a closed-loop supply chain and a reverse omnichannel using blockchain technology and incentives

Received 13 July 2021
Revised 2 January 2022
23 April 2022
12 May 2022
Accepted 13 May 2022

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Abstract

Purpose – This paper aims to analyze the benefits of the blockchain to the circular economy (CE), which is composed of both closed-loop supply chain (CLSC) systems and reverse omnichannel solutions. By ensuring transparency, traceability, visibility and security, the blockchain allows firms to acquire operational capabilities through a CLSC and service capabilities through a reverse omnichannel, which can boost business performance considerably. The related network of relationships can be reinforced by establishing incentives, which entail both smart contracts in the blockchain and active return approaches in CE.

Design/methodology/approach – After identifying the boundaries of the theoretical framework, several research hypotheses are developed according to the literature review and emerging gaps. These gaps link to the impact of the blockchain on CE systems (CLSC and reverse omnichannel), as well as the influence on business performance. The hypotheses are then tested using structural equation modeling and adopting a partial least squares-path modeling technique on a dataset composed of 157 firms. Finally, multigroup analysis is used to test the impact of incentives on the research hypotheses.

Findings – The blockchain facilitates a more efficient CE system, although reverse omnichannel solutions seldom bring any benefits to performance. The shift from a passive to an active return approach must be carefully evaluated. The CLSC network can benefit from an active return approach by developing appealing incentives for collectors and enhancing the positive effects of the blockchain. In contrast, consumer incentives can have detrimental effects on the blockchain. Various combinations of incentives can only bring a few business performance increases, while collector incentives are vital to reinforce the CE system's operational and service capabilities.

Originality/value – This paper takes a new approach toward the study of CE, which considers a dual circular system composed of a CLSC and a reverse omnichannel. The research explores whether the adoption of blockchain technology enables better return processes by improving the operations in CLSC and services in reverse omnichannel. Finally, this is the first empirical work to evaluate the benefits emerging from incentives, which can activate smart contracts in the blockchain and enable active return approaches in CE.

Keywords Circular economy, Blockchain, Closed-loop supply chain, Reverse omnichannel, Incentive mechanisms

Paper type Research paper

1. Introduction

The circular economy (CE) is one of the key topics that have attracted the interest of academics and practitioners in recent decades. On the one hand, environmental pressures stemming from

The author would like to thank Editor Professor Tobias Schoenherr for the valuable suggestions as well as the five anonymous reviewers for the fruitful comments and insights they provided during the review process.

International Journal of Operations & Production Management
Vol. 42 No. 7, 2022
pp. 959-994
Emerald Publishing Limited
0144-3577
DOI 10.1108/IJOPM-07-2021-0445

activism, society and governments oblige firms and supply chains (SCs) to incorporate CE in both their business model and corporate strategies. On the other hand, society at large can enjoy a multitude of benefits linked to CE, such as the reduction of waste and resource consumption, which are pursued through the treatment and recycling of end-of-life products, as well as the activation of a second life through remanufacturing, refurbishing and reusing products. Among the various aspects linked to CE, a closed-loop supply chain (CLSC) has certainly received attention and diffused interest. A CLSC consists of the integration of forward and reverse logistics into a unique system (Govindan *et al.*, 2015), including design, control and operation, to maximize value creation over the entire life cycle of a product (Guide and Van Wassenhove, 2009). The term "closed-loop" refers to the fact that the chain seeks to maintain and recover value from returns (Souza, 2013) while minimizing resource consumption and waste. Accordingly, firms pursuing CLSC must design *ad hoc* take-back programs and manage the circularity of returns to properly close the SC loops (Blackburn *et al.*, 2004).

Although the field of CE has primarily focused on CLSC networks, new forms of collection systems have emerged in modern economies, which are also linked to omnichannel options. When considered in its original form, an omnichannel has played a strategic role in enabling e-commerce and ensuring seamless purchasing experiences for consumers (Levy *et al.*, 2013). However, an omnichannel also offers unimaginable opportunities when applied to CE systems (Xu and Jackson, 2019). In fact, along with its traditional forward functions, an omnichannel is suitable in engaging consumers in reverse activities including returning products to retail stores, shipping them back to manufacturers' or retailers' warehouses and returning them to the manufacturer's factory or a locker (Bell *et al.*, 2014). Therefore, within this study, reverse omnichannel is defined as the firms' capability to offer and integrate various collection options to consumers. These atypical opportunities for closing the loop have inspired this research, which proposes a framework in which CLSC systems and reverse omnichannels live together. Hence, a CLSC will focus on the operational aspects of CE systems while a reverse omnichannel will focus on the service sides of CE systems.

We identified several business cases that reinforce the motivation to study reverse omnichannel within CE systems. A research study conducted by Lau *et al.* (2015) demonstrates that 72% of consumers who make purchases online return such products in a physical store, thereby activating reverse omnichannel options. Within a theoretical framework, Jin *et al.* (2020) study how the configuration buy-online-return-offline offers important opportunities to create competitive advantages. The analysis of a dual reverse strategy represents a novelty in the extant literature, which has primarily focused on CLSC systems to assess the convenience of CE. These collection opportunities inspire this research, whose first target is to develop a theoretical framework through which CE can be managed by simultaneously using both CLSC networks and reverse omnichannel options.

Although including both the CLSC and reverse omnichannel entails further circular opportunities, the increased challenges linked to the CE system requires the support of digital technologies (Wang *et al.*, 2020; Rosa *et al.*, 2020). Due to multiple uncertainties surrounding the CE systems, the blockchain has been shown to be a suitable technology to properly close the loop and ensure trustable returns (Bekrar *et al.*, 2021). In fact, firms do not have information on how consumers use a certain product, whether it is subject to regular maintenance, or whether the consumers use it properly. Instead, the blockchain records information during the entire life cycle of products through authorized systems, including the return phases. As a result, it can guarantee a trustworthy assessment of the environmental impact over the life cycle and a true estimation of the residual value of returns (Bai and Sarkis, 2020), which are both key ingredients to achieve the target of responsible digitalization (Cardinali and De Giovanni, 2022). Similarly, consumers and firms always face the issue of the origin and provenance of returns and have to rely on the pieces of information that are either displayed on the labels or obtainable from secondary sources. In contrast, the blockchain ensures the provenance of returns that are uniquely and properly identified, classified and documented in immutable and accessible records (Chang *et al.*, 2020). Accordingly, the blockchain demonstrates firms' and stakeholders' responsible behaviors and ensures that the CE systems aim at improvements in economic, social and environmental performance (Bai and Sarkis, 2020). Therefore, it entails responsible digitalization targets, which describes the firms' capacity to identify and implement the digital technologies to perform the triple bottom line and achieve corporate social responsibility goals (Cardinali and De Giovanni, 2022). Although blockchain technology may offer significant advantages to CE systems, the extant literature calls for further developments, especially within sustainable systems (Mastos *et al.*, 2021). In fact, previous research has primarily focused on the implications of the blockchain either for traditional SCs or for the CLSC (e.g. Bekrar *et al.*, 2021), while disregarding its impact on dual CE systems, including the CLSC and reverse omnichannel. Therefore, the second target for this research pertains to the benefits that the blockchain can yield when CE systems are composed of both the CLSC and reverse omnichannel.

Finally, CE systems are characterized by the involvement of networks of firms, as well as multitudes of consumers. Such involvement can be either passive (also called the waste-stream approach) or active (also called the value-stream approach) (Genc and De Giovanni, 2017). In a waste-stream approach, firms wait passively that both consumers and collectors return end-of-use and/or end-of-life products on a voluntary basis, according to their environmental sentiments and wishes to prevent the environment for future generations. In contrast, in a value-stream approach, firms offer incentives to consumers and/or collectors to encourage an active return of end-of-use and/or end-of-life products by receiving a certain reward (Genc and De Giovanni, 2017). The theoretical literature on the CLSC has broadly investigated the incentive mechanisms for collectors and consumers as enablers of CE systems (see De Giovanni and Zaccour (2022) for a recent survey on the incentive mechanisms). These incentives, implemented in blockchain systems, are justified through the behavioral agency theory developed by Pepper and Gore (2015), according to which the interests of shareholders and their agents are most likely to be aligned when agents are motivated to perform to the best of their abilities, given the available opportunities. However, to our knowledge, no empirical research investigates how to make use of the behavioral agency theory through the incentives written on the blockchain and actionable through the smart contracts. Therefore, the third objective of this research is to analyze whether moving from waste-stream (passive) approach to value-stream (active) approach to return renders a dual CE system more effective. Since we investigate CE systems that are composed of both CLSC and reverse omnichannel, both incentive types (one for collecting firms and one for consumers) are applicable. On the one hand, the adoption of incentives enables a CE system to shift from a waste-stream approach to a value-stream approach. On the other hand, firms adopting the blockchain can make use of incentives to activate the smart clauses in smart contracts. Therefore, the incentives can play the dual role of enabling active CE systems and activating smart contracts in the blockchain.

To accomplish the three aforementioned research targets, we identify a theoretical framework and develop several research hypotheses. We begin the analysis by investigating the benefits that blockchain technology adds to a dual CE system composed of a CLSC and a reverse omnichannel. Hence, we seek to verify whether the blockchain is an effective technology to improve CE in its dual form. We, then, explore the real advantages obtainable from digital transformation through blockchain technology and the implementation of a dual CE system by analyzing their impact on performance. Finally, we contribute to the literature by searching for the benefits attainable when firms provide incentives to collectors and/or consumers. In fact, blockchain technology embeds incentives within the clauses of smart contracts, hence considering them within our research design as well as according to the behavioral agency theory originating a novel contribution. We test the research hypotheses on a sample of 157 firms by using structural equation modeling and assessing the effects induced by the incentive mechanisms through a multigroup analysis.

The remainder of the paper is structured as follows. Section 2 introduces the literature review on the subject and develops the research hypotheses. Section 3 displays all of the details surrounding the methodology we employ and the empirical support we obtain. Section 4 reports the empirical results. Section 5 discusses the findings and highlights the managerial implications. Section 6 reports the theoretical contributions while Section 7 concludes and identifies directions for future research in the same domain.

2. Theoretical background and hypotheses development

Since the blockchain is a general purpose technology that seeks to unlock the value of information (De Giovanni, 2020), it naturally enables new processes, opens new business and social opportunities, and implies complementary procedures (van Hoek, 2019). In fact, the blockchain supports existing innovations and systems to achieve new and original goals directly induced by the digital transformation (Zhu and Kouhizadeh, 2019). The literature has demonstrated its potential benefits in several traditional SC directions, including performance, transparency, visibility, security and traceability (Wamba *et al.*, 2020; De Giovanni, 2020; Bekrar *et al.*, 2021).

Interestingly, applications of blockchain technology have also emerged in the field of sustainable SC applications. For example, Saberi *et al.* (2019) discuss the use of the blockchain for sustainable SCs. Unethical suppliers' behaviors and actions, the presence of counterfeit products or the use of wrong production procedures are generally not visible to SC members, and the content of information and data is not secure and transparent. Instead, the blockchain records these pieces of information by authorized actors, making them secure through immutable systems and transactions as well as transparent and visible to all SC members who wish to have an access. As a result, the blockchain may effectively prevent social issues like corruption of individuals, governments or organizations. Such benefits, which are feasible when using the blockchain in sustainable SC frameworks, can be also obtained in CE contexts. By exploiting the features of traceability and visibility, Manupati *et al.* (2020) create a blockchain monitoring system that matches SC performance based on emissions and costs, with the government's carbon restriction and regulation. The use of the blockchain regulates the carbon exchanges and ensures environmental performance and standards. Within similar research frameworks, the blockchain has been shown to be highly beneficial in the context of sustainable water management (Zhao *et al.*, 2019), sustainable agriculture SCs (Kamble *et al.*, 2020), transport and logistics (Koh *et al.*, 2020), control of CO_2 emissions (Biswas *et al.*, 2022) and waste management (Mastos *et al.*, 2021).

Although the assessment of the blockchain has been documented in several studies linked to sustainable SCs, the blockchain has seldom been investigated when applied to CE. The recent works by Kouhizadeh *et al.* (2020) and Bekrar *et al.* (2021) highlight how the blockchain can provide several advantages for CE. For example, without using the blockchain firms are not able to trace the real use of a good during the life cycle or the composition of a recycled material. Consequently, it becomes difficult to estimate the real returns' residual value, its composition and the residual life. Instead, by continuously recording information, the blockchain ensures traceability over the CE system and makes such information visible and accessible. Inspired by the worldwide effects of COVID-19, Nandi *et al.* (2021) investigate the possible responses that blockchain enabled CE can provide to SC problems and issues that have emerged during the pandemic. Several business aspects are analyzed, and different possible practices are proposed in a theoretical and conceptual framework. Böckel *et al.* (2021) carry out a review of blockchain studies in CE and find a mismatch between theory and practice when the blockchain is applied to CE. The authors highlight that although the potential for the blockchain can be very helpful in CE, questions must still be resolved regarding whether the blockchain can accelerate the move toward a circular economy. With the intent of contributing within this domain, we analyze the impact of the blockchain on a dual CE system composed of a CLSC and a reverse omnichannel.

Currently, there is a gap in the literature regarding the real benefits that the blockchain can grant to a CLSC. These advantages have been explored by two approaches: theoretical and empirical. Regarding the theoretical approach, De Giovanni (2021) uses a game theory approach to investigate how the blockchain can incentivize firms to pursue a more efficient CLSC process by continuously monitoring the residual value of returns. Hence, he suggests using the blockchain to mitigate distortions linked to the returns' uncertainty surrounding quantity, quality and time.

Using an empirical approach, Farooque *et al.* (2020) show that the blockchain offers very important opportunities for closed-loop applications, although the technology's limited maturity, governance changes, and lack of culture and regulation among suppliers may seriously limit its adoption. The authors apply a decision-making trial and evaluation of laboratory (DEMATEL) method to a sample of Chinese companies that had experiences with the blockchain to highlight the barriers that firms face when implementing the blockchain to the life cycle assessment. Similarly, Rehman Khan *et al.* (2021) analyze the impact that the blockchain exerts on CE, where the latter is measured through manufacturing-based variables including recycling and remanufacturing, green manufacturing, and green design.

According to the extant literature, the blockchain records information on the entire history of returns that is linked to the complete life cycle and can be accessed by consumers, firms and suppliers using a simple tag. Therefore, the blockchain can collect and record information at each stage of the return process within CLSCs and make it available to the society at large. However, the literature exhibits a gap regarding the benefits that the blockchain can grant to a CLSC, which goes beyond the residual value of the returns (as in De Giovanni (2021)) and manufacturing-based practices (as in Rehman Khan *et al.* (2021)) and requires the conceptual frameworks (e.g. Bekrar *et al.*, 2021) to be verified empirically. Therefore, we seek to fill this gap by investigating the benefits that the blockchain grants to a CLSC, and by developing the following research hypothesis:

H1. The adoption of blockchain technology has a positive impact on the management of CLSC systems.

Continuous technological development and globalization, coupled with rapid changes in consumers' purchasing habits, have forced firms and SCs to integrate offline and online channels to provide a seamless customer experience (Levy *et al.*, 2013) by implementing omnichannel strategies. The literature has extensively detailed the potential advantages and applications of the omnichannel (e.g. Brynjolfsson *et al.*, 2013). Even though the process of implementing omnichannel solutions introduces high complexity, leaving issues related to efficiency and lack of transparency (Abeyratne and Monfared, 2016), the need for fast deliveries, flexible orders and compliance with regulations or quality standards obliges firms to seek out and pursue its adoption (Welfare, 2019). These challenges are complemented by additional features of complexity linked to the CE and the existence of a well-defined CLSC structure and return process (Frei *et al.*, 2020). In these circumstances, the reverse logistics' flows must integrate with the forward flows over all existing channels in an omnichannel solution, in which consumers have different options for returning their products, collectors optimize the logistics path according to the locations defined in the omnichannel strategy and the return process can exhibit high degrees of uncertainty (Naclerio and De Giovanni, 2022).

A reverse omnichannel strategy can be defined as a set of possible options given to consumers to finalize the return process. It can be seen as information surrounding the return points, stock keeping points and product reverse flows that are retrievable, traceable and changeable over all channels (Ahsan Rahman *et al.*, 2022). The literature is quite rich in terms of the analysis of omnichannel solutions linked to forward goods (McCharty *et al.*, 2019), in which process consumers can purchase either online or offline and receive the delivery at home (e.g. home delivery), at a certain location (e.g. lockers) or at a company's location (e.g. delivery to a store). However, a research gap exists when searching for reverse omnichannel solutions. The literature has most likely focused on the existence of multichannel options to manage returns. Therefore, for example, consumers can make a purchase either online or in-store; then, the return of products purchased online (in-store) will be done online (in-store) as well. Once again, the survey by De Giovanni and Zaccour (2022) reveals the existing contributions in that direction. In contrast, the omnichannel integrates all channels made available by firms; hence, for example, a product purchased online can be returned to a store. Accordingly, the return process can be finalized through a direct channel in which end users send goods back to manufacturers or through an indirect channel in which end users return goods to manufacturers through third parties (e.g. retailers and specialized collectors) or by using a combination of both.

To our knowledge, Ma *et al.* (2013) is the sole game theory-based study on the return process managed by e-retailers. Hereby, the CLSC finds incentives in some government subsidies to implement and manage a dual-collection channel CLSC. Ma *et al.* (2013) compare firms' strategies by analyzing the impact of subsidies and find that e-retailers can be highly challenged by the return process. The latter is highly influenced by both government subsidies as well as consumer willingness to purchase and return from e-tailers comparatively to retailers.

These contributions lack a proper analysis of a reverse omnichannel strategy that, within the forward omnichannel strategies, consists of several combinations between the activation of the return process and the physical collection of products. Therefore, reverse omnichannel strategies require end users to have the chance to return their goods by initializing the return process, either online (e.g. through an app) or offline (e.g. visiting the seller), and to finalize the return process either by having collectors visit their home (e.g. home collection), having them go to a certain location (e.g. return to a collecting location) or meeting at a company location (e.g. return to the seller's location). Here, we insert our contribution by developing the concept of a dual CE system, which consists of all possible reverse omnichannel solutions implementable according to the CLSC. To guarantee the success of a dual CE system, firms managing CLSCs should rethink the possible need to implement a reverse omnichannel and also guarantee a seamless consumer experience when dealing with reverse flows.

Within this context, we consider the CLSC to be an antecedent of the reverse omnichannel. This statement is evident when analyzing all papers using simulation and theoretical models to investigate circular economy systems (e.g. Souza, 2013; Govindan *et al.*, 2015; Ma *et al.*, 2013; De Giovanni and Zaccour, 2022); accordingly, having an efficient and robust CLSC structure ensures that the collection done through either traditional (e.g. retailers) or atypical channels (e.g. e-tailers) is operationally doable and economically feasible. Therefore, the CLSC provides the operating structure, requires *ad hoc* operational capabilities and implies considerable investments to be made. Examples of such investments are recycling facilities and technologies based on chemical recycling. Instead, the reverse omnichannel grants returning options to consumers, requires capabilities that are linked to services and implies soft investments for firms. Examples of such soft investments are providing consumers the opportunity to return to the store or to a drop-off location (Deloitte, 2020). Furthermore, a CLSC system without a reverse omnichannel option is frequently adopted in practice (e.g. closing the loop in the paper industry requires a direct link with the municipality, while reverse omnichannel options do not apply). In contrast, a reverse omnichannel without the CLSC would not be operationally efficient (e.g. offering a return to locker option without having the operational structure to collect from lockers). Finally, we develop the relationship between the CLSC and reverse omnichannel within the context of adopting blockchain technology, which allows one to first record information on the operating and production structure and then to trace and enrich it through information on the reverse omnichannel. Accordingly, the reverse omnichannel finds application and becomes a feasible option only when a CLSC system exists and ensures adequate logistics and operations activities for handling and supporting the returns. Then, we hypothesize the following:

H2. The management of CLSC systems has a positive impact on the implementation of reverse omnichannel options.

In addition to providing the benefits identified in previous discussions, several recent contributions have demonstrated the success of blockchain technology in pursuing the omnichannel's targets. This evidence has been documented in several case studies and applications. According to Kamath (2018), Walmart has solved the SC's problems of transparency, traceability and visibility across the globe and all channels by using the blockchain. In fact, Walmart has a complex SC composed of thousands of manufacturers and stores coordinated within various channels. The transactions occurring in the global chain have raised issues surrounding the authenticity and treatment of mangoes and meat pork. Walmart tackled these issues by implementing the blockchain and, consequently, making the information fully visible to consumers in all available channels (Hyperledger, 2019). Similarly, Carrefour uses blockchain technology to guarantee the authenticity of free-range chickens. Independent of purchasing online or offline and asking for specific delivery preferences, consumers can access all information through the blockchain (Capgemini, 2018). Barilla adopted the blockchain to control every moment of the basil production chain to guarantee the quality of the "Made in Italy" label (Prandelli and Verona, 2020). This information is available to consumers in all of Barilla's channels. LVMH (Moët Hennessy Louis Vuitton) is experimenting with the blockchain to allow consumers to trace the entire history of the products, from the raw materials used to manufacturing and distribution, with the intent of guaranteeing the products' authenticity within the omnichannel strategy (Choi, 2020).

Although the aforementioned cases document the benefits that the blockchain provides to consumers and firms dealing with (forward) omnichannel solutions, a research gap exists regarding the possible positive effects that the blockchain can offer to the reverse omnichannel. To our knowledge, this is the first study that deals with the possible adoption of the blockchain to unlock the value of reverse omnichannel options. The importance of the reverse omnichannel has already been documented in multiple case studies and applications. For example, Apple, Samsung and other similar companies in the electronics sector offer consumers the opportunity to use reverse omnichannel options to deal with returns. The Apple's return program allows end users to activate an online procedure to return a device for possible evaluation, which ends with the proposition of a rebate to consumers. If consumers accept the deal, they receive a rebate; if the deal is rejected, the product is sent back to consumers using reverse omnichannel options, including collection from certain locations and home delivery (see the Apple's website, www.apple.com for more details). In the cloth industry, Zalando offers the opportunity to return unsatisfactory items by either returning them to the company or sending them back to the store (eventually the items had been purchased through a store), or dropping them off at a partner's (see DHL's website www.dhl.com for more details) location the consumer selects, leaving them in a locker or scheduling a pickup service (see the Zalando's website www.zalando.co.uk for more details). While Zalando has historically offered return omnichannel services for free, it is now rolling out a different policy in several countries, according to which consumers will pay a return fee of 3.5€ for orders below 25€ (Deloitte, 2020). This radical change is attributable to the heavy use of the reverse omnichannel by consumers.

Within the entire CE process developed in a traditional omnichannel, consumers can at most track the returned goods, conditionally to a third party connected to the system (Naclerio and De Giovanni, 2022). Meanwhile, several issues can emerge from the return process. For example, are the return conditions altered during the transport or evaluation processes? Are the returns subject to critical and drastic temperature changes when closing the loop? What types of activities are truly carried out by the manufacturers when evaluating the goods? How long does the process take to finalize each activity? Which person or team deals with the returns? The use of the blockchain can keep consumers informed of all of these aspects of the return process, even when it occurs through omnichannel options.

This set of information, which represents only a short list of all possible issues linked to the return flow in reverse omnichannel solutions, is not available to end users and raises several doubts about whether the return process is carried out properly, fairly and respectfully in response to social and environmental concerns (Pournader *et al.*, 2020). The blockchain can serve as the optimal technology to guarantee this level of detail during the entire return process carried out through reverse omnichannel options (Kouhizadeh *et al.*, 2020). Each task is carried out, from when the goods leave the consumers' home (the reverse logistics' first mile) until they reach the end of their path through the CLSC (the reverse logistics' last mile) and can be recorded on the blockchain and publicly accessed by anyone (Naclerio and De Giovanni, 2022). Although empirical (e.g. Wamba *et al.*, 2020) and theoretical research (Kouhizadeh *et al.*, 2020) demonstrates blockchain's effectiveness in supplying highly accurate and detailed information during the forward processes (Pournader *et al.*, 2020), research must still be developed to characterize, analyze and test the effect of the blockchain on the reverse omnichannel. Accordingly, we introduce the following hypothesis:

> *H3.* The adoption of blockchain technology has a positive impact on the implementation and management of reverse omnichannel options.

The operational and economic benefits that the blockchain grants to firms have been well documented in the literature (Kshetri, 2018). These benefits link to several business functions such as manufacturing, transportation, procurement and logistics (van Hoek, 2019) and can be observed for both general strategic purposes (e.g. increasing the brand reputation) to specific purposes (e.g. solving the last mile issues) (Naclerio and De Giovanni, 2022). Different from traditional IS (information systems) where the information is centralized, the blockchain ensures that all the SC members and the stakeholders involved in a certain transaction share the same verified information, which is then decentralized (Hackius and Petersen, 2017). By granting SC visibility, the blockchain allows firms to optimize the whole network of relationships behind the SC and work with diffused trust, commitment and transparency; hence, the traditional monitoring mechanisms are not necessarily needed (De Giovanni, 2021). In fact, the firms can use the blockchain to verify and monitor the state of products in each SC tier (Welfare, 2019) and automatically record information by using both the digital technologies and the oracles; those systems allow the smart contracts to be updated accordingly (De Giovanni, 2021) and keep track of SC members' and stakeholders' performance and behaviors (Lakhani and Iansiti, 2017). The final consumers can also enjoy the benefits of the blockchain by accessing trustworthy and verified information that enhances the value of the goods purchased (De Giovanni, 2020).

In general, the literature emphasizes the economic improvements that the blockchain guarantees to SC members. By developing an empirical research, Ko *et al.* (2018) show the positive effects of blockchain technology in terms of real-time transparency and reduced costs, which exert a positive influence on the business profitability. The blockchain is an effective driver in documenting all information regarding the product by recording information on the processes behind it, such as the material used in production, the machines used in each production cycle, operators who have finalized a batch of tasks and the energy consumed in each step (Mastos *et al.*, 2021). Therefore, all performance linked to each step of the product life cycle can be verified and recorded in the blockchain. This level of detail offers extensive knowledge throughout the production journey, highlights possible inefficiencies and activates smart contracts to remove them (Naclerio and De Giovanni, 2022). According to the literature highlighting a positive link between blockchain technology and performance, we hypothesize the following:

H4. The implementation of blockchain technology has a positive impact on a firm's business performance.

Offering collection options and take-back services is a common practice for all CE businesses. Clearly, this practice implies the use of a CLSC that accounts for a hard collection structure (e.g. recycling operations, technology investments and warehouses), as well as a reverse omnichannel that guarantees some collection options (e.g. return to the store, return to a collection point and return to the manufacturer). As a part of the firms' business model, the main motivation for pursuing a CE system through both the CLSC and reverse omnichannel is to increase firm performance (Bekrar *et al.*, 2021).

This statement clearly emerges from all research investigating various CLSC structures, in which firms search for the best CLSC system to improve performance and find confirmation from both theoretical and empirical works. Regarding the theoretical research field, the study by Savaskan *et al.* (2004) is the first paper to have searched for the best collection structure to make the CLSC profitable, and to have analyzed whether to collect through a centralized system or through a manufacturer, a retailer or third-party logistics. The study by Savaskan *et al.* (2004) has been followed by numerous articles in which this research question has been tackled from multiple perspectives, including collection options and collection variants (e.g. e-tailer), atypical practices (e.g. quality check for returns) and various stakeholders (e.g. government). We refer readers to the work by De Giovanni and Zaccour (2022) for a comprehensive survey on CLSC structures and their effects on firms' performance.

Regarding the empirical research, studies on the CLSC and performance are limited. The empirical study by Bhatia and Kumar Srivastava (2019) investigates the impact of CLSC antecedents on both environmental and economic performance. Such antecedents refer to product recovery, production planning, environmental concerns, demand and inventory management, organizational leadership, sustainable production, raw material prices, as well as product design and collection. Hence, they demonstrate the need to engineer the CLSC system since it may not be economically sustainable. In their empirical analysis, Bhatia and Kumar Srivastava (2019) show that economic performance is positively influenced by environmental concerns, raw material prices, and demand and inventory management. In contrast, all components strictly linked to return management and remanufacturing have no significant effect on economic performance. The second empirical study by Shaharudin *et al.* (2017) analyzes the impact of the CLSC on the effectiveness of the return process; therefore, the authors focus on the operational benefits of the CLSC. The latter consists of improvements in terms of scrap rate, cost savings, purchasing cost, waste and commitments to environmental practices. Testing their hypotheses on a sample of 150 firms, Shaharudin *et al.* (2017) find a positive and significant association between the CLSC and the effectiveness of the reverse process. Finally, the third empirical study by French and LaForge (2006) differentiates between internal and external returns and empirically investigates them in detail. Although the authors do not conduct any performance tests, the study clearly indicates that internal returns, representing 65.83% of the total, are cheaper and less complex to manage than external returns, which consists of 34.17% of the total returns. According to the literature review, there has been diffused interest in the theoretical research with regard to investigations into the impact of the CLSC on economic and business performance. In contrast, a research gap emerges from the empirical literature regarding empirical evidence of the benefits that the CLSC exerts on firm performance. Therefore, we formulate the following research hypothesis:

H5. The management of CLSC systems has a positive impact on a firm's business performance.

Much like the CLSC, reverse omnichannel solutions are also motivated, among other factors, by the significant opportunity to increase firm performance. Ma *et al.* (2013) demonstrate the benefits of an omnichannel in reverse logistics through e-tailers who enjoy a considerable increase in performance; thanks to government subsidies offered to close the loop. Guerrero-Lorente *et al.* (2017) characterize a model with a mix of orders and return flows to allow decision makers to minimize costs while analyzing the overall tradeoffs linked to different types of available omnichannel options. Mandal *et al.* (2021) characterize a theoretical model to prove the convenience of adopting reverse omnichannel options, with a particular focus on two options: buy online/return to store and buy online/return online. The choice regarding the most suitable option depends on product standardization and valuation, which have a considerable impact on firm profits. Following the same line of thought, Nageswaran *et al.* (2020) analyze these two options by investigating the effect of refunds. The authors focus on the analysis of partial refund and full refund policies, which are both set in conjunction with pricing strategies in each of the investigated reverse omnichannel options. Nageswaran *et al.* (2020) demonstrate that firm profits are dependent upon the reverse channel that consumers prefer, which is primarily driven by incentive taking in the form of full refunds for in-store returns and partial refunds for online returns.

The literature presents some qualitative research on the impact of the reverse omnichannel on performance, focusing on comparative case studies. Bernon *et al.* (2016) analyze the benefits that the reverse omnichannel has on performance by comparing the strategies adopted by 15 firms and their related outcomes. Their findings demonstrate that the reverse omnichannel has a considerable impact on performance, such as returns, cost savings, environmental performance, inventory and sales, and suggest rethinking the reverse omnichannel as a strategic weapon to increase performance and competitiveness. Saghiri *et al.* (2017) collect information from seven companies implementing omnichannel strategies and offering several types of return programs. The CLSC is integrated within the entire system through the *ad hoc* return process promised to consumers, with return price guaranteed, a recycling price provided, delivery point information, a return policy based on product features (physical and functional information) and consumer feedback. They demonstrate that the most efficient omnichannel return processes are manufacturers collecting from homes (Westbridge Forniture), retailers collecting through shops (Argos, John Lewis, Wren and Tesco), digital retailers collecting either from homes or through drop-off points (Ocado and Tesco), and third-party collection, either from homes or through drop-off points (Amazon, Westbridge Forniture and Wren). These return omnichannel configurations allow firms to obtain higher visibility in terms of the product, demand, inventory and SC. However, the return omnichannel cannot deliver other performance features, such as order and payment visibility, as well as visibility of shipment and delivery.

As suggested by Xu and Jackson (2019), the extant literature calls for further empirical analysis regarding the impact of the reverse omnichannel on performance. To our knowledge, the sole contribution by Xu and Jackson (2019) empirically investigates the impact of the reverse omnichannel on consumer attitudes toward the return of goods. All attributes the authors investigate empirically aim at increasing consumer loyalty in choosing the return channel. We move the focus from customers to firms and contribute to this body of knowledge by investigating the impact of the reverse omnichannel on firm performance and developing the following research hypothesis:

H6. The implementation of reverse omnichannel options has a positive impact on a firm's business performance.

2.1 The impact of incentives

As has emerged from the literature review, although there is clear evidence of the positive effects induced by CE to the ecosystem and society at large, the key topic that must still be addressed is how firms can engage consumers and collectors in contributing to the system circularity. In fact, without responsible and conscious behavior to collect, the CE system will never acquire a sufficient feedstock for the efficient management of circular activities. The literature has focused on two major return approaches aimed at achieving circularity: a passive return approach and an active return approach (Blackburn *et al.*, 2004; Genc and De Giovanni, 2017).

In the passive return approach, also referred to as the waste-stream approach, collection happens on a voluntary basis, and the CE system is primarily considered a cost center; therefore, neither firms nor consumers that are part of the CE system receive any incentive for closing the loop. Rather, they are motivated by their own responsible sentiment and willingness to preserve the environment for future generations. In contrast, an active return approach, also referred to as a value-stream approach, implies that the CE system is managed as a value creation center, through which collectors and consumers involved in the collection process receive a reward as a counterpart for their responsible actions. Therefore, whoever collects is actively incentivized to undertake responsible behaviors.

Currently, firms struggle to identify the best type of incentive to unlock CE potential. Within the active return approaches, the theoretical literature has identified two possible incentive mechanisms, which basically link to the entity responsible (either a consumer or a collector) for managing the return process. The first incentive mechanism is given to consumers under the form of rewards, fidelity points and/or discounts on future purchases, and is called the *consumer incentive*. The second incentive is given to collectors under the form of economic rewards based on the returned quantity, quality, timing, commercial advantages or support on joint investments, and is called the *collector incentive*.

Interestingly, when circular systems make use of an active return approach, the blockchain can activate smart contracts in both cases of consumer and collector incentives. By using inbound and outbound oracles, as well as software, hardware and human oracles, the smart contracts activate incentives for both consumers and collectors when they have performed as written in the smart clauses (De Giovanni, 2022). This integration between the blockchain, the circular economy and incentives represents a revolution in the creation and management of circular systems and can be an effective way to increase the feedstock. In this sense, the smart clauses in blockchain technology are defined according to the behavioral agency theory developed by Pepper and Gore (2015), according to which the principal wishes to align to the agent's objectives to the principal's own objectives and motivate agents to achieve high performance given their abilities and opportunities. The blockchain can then be used to align the firm's objectives to the consumers' and the collectors' objectives, motivations and abilities to achieve high performance levels in CE systems.

To develop a novel theoretical framework, we consider both the incentives for consumers and the incentives for collectors and integrate them with CE systems and blockchain technology, as described in Table 1. We then refer to $Incentive_{IJ}$ as the incentive, I offered to consumers and Incentive J offered to collectors. We use the notation $I = \{C, \overline{C}\}$ and $J = \{C, \overline{C}\}$ with the following meaning: $I = C$ means that an incentive for consumers exists, $I = \overline{C}$ means that no incentive for consumers exists, $J = C$ means that an incentive for collectors exists, and $J = \overline{C}$ means no incentive for collectors exists.

Accordingly, we can identify four combinations of incentives, which are classified as follows:

Table 1.
The theoretical framework with the CE system, the blockchain and incentives

	Collector incentives	No collector incentives
Consumer incentives	*Value-stream approach* The CE system engages in an active return (value-stream) approach. The blockchain activates the smart contracts based on both consumer and collector incentives	*Consumer-based value-stream approach* The CE system engages in a partially active return approach by focusing on consumer incentives. The blockchain activates the smart contracts according to consumer incentives
No consumer incentives	*Collector-based value-stream approach* The CE system engages in a partially active return approach by focusing on collector incentives. The blockchain activates the smart contracts according to collector incentives	*Waste-stream approach* The CE system does not engage either consumers or collectors in the collection of production, being *de facto* passive. The blockchain does not activate the smart contracts based on incentives

(1) Incentives to both consumers and collectors, namely, $Incentive_{CC}$, which implies the implementation of a *value-stream approach (or active return approach);*

(2) Incentives to consumers but not also to collectors, namely, $Incentive_{C\bar{C}}$, which implies the implementation of a *consumer-based value-stream approach;*

(3) Incentives to collectors but not also to consumers, namely, $Incentive_{\bar{C}C}$, which implies the implementation of a *collector-based value-stream approach; and*

(4) Incentives neither to collectors nor to consumers, namely, $Incentive_{\overline{CC}}$, which implies the implementation of a *waste-stream approach (or passive return approach).*

Therefore, we test the differences in our research hypotheses against these groups to provide some managerial prescriptions and insights. Specifically, we seek to answer to the following research question: *Which incentive types should firms put in place to enhance business performance by boosting the effectiveness of the blockchain, CLSC and reverse omnichannel?* We expect to identify and suggest the best package of incentive mechanisms to reinforce the impact of the blockchain on CE systems and, above all, identify the incentive mechanisms to increase firms' business performance. Accordingly, the research hypotheses also consider consumer and collector incentives and take the following form:

When offering $Incentive_{IJ}$ rather than other types of incentives, it results the following:

H1a. The adoption of blockchain technology has a higher positive impact on the management of the CLSC system.

H2a. The management of a CLSC system has a higher positive impact on the implementation of reverse omnichannel options.

H3a. The adoption of blockchain technology has a higher positive impact on the implementation of reverse omnichannel options.

H4a. The implementation of blockchain technology has a higher positive impact on a firm's business performance.

H5a. The management of the CLSC has a higher positive impact on a firm's business performance.

H6a. The implementation of reverse omnichannel options has a higher positive impact on a firm's business performance.

Figure 1 summarizes and displays all research hypotheses proposed in this research.

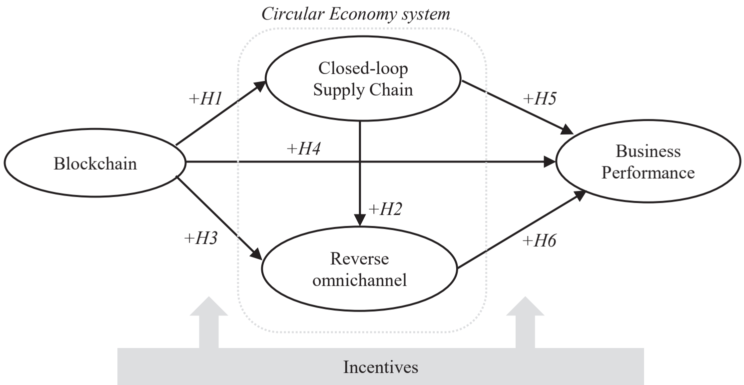

Figure 1. Conceptual model

3. Methodology

3.1 Survey design and sample description

Considering the purposes of our research, we collected primary data by designing and administering a survey. Then, we focused on pieces of information linked to the respondents (e.g. industry, country, size and company type), the firms' investments in blockchain technology, the CLSC network and the reverse omnichannel, as well as the firms' business performance in the last two years. The questionnaire, which was composed of eight sections and included 82 questions also referred to other topics than the ones analyzed in this research (Naclerio, 2020), and was pretested on a pool of experts (professors, PhD students, professionals and managers) from whom we requested feedback about wording, readability and completeness. The survey, which is displayed in Table A1, was then modified and improved accordingly.

The data used in this study were collected through questionnaires sent to firms selected through Bureau van Dijk Electronic Publishing, which combines high quality information with innovative software in order to search for and manipulate data. Since the entire research project focuses on digital transformation and supply chain management, we selected the sample firms by checking through secondary information whether the firms had undertaken digital transformation processes and had an interest for circular economy. We submitted the survey to an initial sample of 1,200 firms. Since the operational responsibility of a dual circular economy system is most likely linked to SC management, we requested that the answers could be given by the SC manager. When missing, the answer could be given by other managers linked to SC management like managers of operations, logistics, sales, production, purchasing, procurement and distribution. The managers were contacted via email with the kind request of a multirespondent approach based on which at least three managers of the same team would have responded. Within two weeks, we received the majority of the responses. In the meantime, we extended our investigation by contacting them by phone. By the end of November 2020, we obtained a total of 157 usable observations, excluding those removed as invalid. This represents about 12% of the entire population of companies that we targeted (1,200). The sample size is in line with previous empirical research in the domain. For example, the sample size was 138 firms in Bhatia and Kumar Srivastava (2019), 150 firms in Shaharudin *et al.* (2017) and 141 firms in French and LaForge (2006).

More than half of the organizations had average sales of more than 100 million (52%) and a workforce of more than 200 employees (53%). Although several professional figures responded to our survey, the majority of them were SC managers (52%) and working most likely in manufacturing (36%) and retailing (23%). The final sample was composed of firms belonging to different sectors, with an important presence of firms working in the food and beverage industry (22%) as well as in the fashion and apparel industry (12%). Table 2 displays all the details regarding both the respondents and the composition of the sample.

Several approaches were used to assess the nonresponse bias. The first approach consisted of comparing early and late respondents (i.e. first and second to third surveys). A one-way analysis of variance (ANOVA) done on all items found no significant differences between the early and late responses. Accordingly, nonresponse bias was not present. Moreover, the nonresponse bias was checked through the demographic variables size, the number of employees and sales. Once again, we found no significant differences between the groups.

We used a seven-point Likert scale to measure the items of the questionnaire to capture the level of agreement with a question. Accordingly, 1 signified "not at all in agreement" and 7 signified "full agreement". Considering the importance of the difference between the items, the analysis was conducted at the original scale for all items.

3.2 Estimation methods

To achieve the objectives of this study, we used partial least squares path modeling (PLS-PM) and the XL-Stat 2021.2.1 software. PLS-PM is a component-based estimation algorithm that aims to predict the relationships between constructs and provides their scores at the original scale (Agyabeng-Mensah *et al.*, 2020). Furthermore, PLS-PM does not require any distributional assumption for the data (in contrast with a maximum likelihood covariance-based approach). Finally, PLS-PM provides less biased estimates than other approaches to structural equation modeling sample sizes lower than 200 observations, while achieving the same power above 200 observations (Chin, 2010). These motivations underlie the use of PLS-PM in several business contexts, such as operations management (Peng and Lai, 2012), SC management (Colicev *et al.*, 2016), sustainable SC (Agyabeng-Mensah *et al.*, 2020) and CLSC (Bhatia and Kumar Srivastava, 2019).

3.3 Model assessment

According to the meaning that we give to each of our constructs, we use reflective scales for all items to measure the firms' capability in a certain domain. Therefore, we follow the procedure suggested by Colicev *et al.* (2016) and Agyabeng-Mensah *et al.* (2020) to check for the internal consistency of constructs as well as to verify both the convergent and the discriminant validity.

The CLSC is composed of a set of items linked to the closed-loop network and activities that firms establish to guarantee CE targets. In developing this scale, we have been inspired by the scales used by Bhatia and Kumar Srivastava (2019) and Shaharudin *et al.* (2017). More specifically, CLSCs require the activation of some recycling options (CLSC1) that support the traditional CLSCs, such as refurbishing and remanufacturing returned items (CLSC2). These activities must be transferred to *ad hoc* information systems (CLSC3) that properly manages and integrates all flows, along with external bodies that carry out the collection activities (CLSC4). Finally, the CLSC is also exemplified by the management of replacement goods (CLSC5) for consumers who are immediately engaged when returning products and selecting from various cheap return options (CLSC6).

Regarding the construct Business Performance (BP), we make use and revise the scales developed by Bhatia and Kumar Srivastava (2019), who consider both economic and environmental components when studying performance within the context of the CLSC. Along with these revised scales, we also considered other traditional items like market share and return on investments (ROI) included in the scales by many contributions (e.g. Agyabeng-Mensah *et al.*, 2020). Therefore, our scale includes the items the market share

Table 2. Sample description

Sales	#	%	Employees	#	%	Country	#	%	Company type	#	%	Professionals	#	%	Industry	#	%
< 10	11	7.0%	< 50	14	8.9%	Europe	115	73.2%	Manufacturer	56	35.7%	SC manager	82	52.2%	Food and beverage	34	21.7%
10–50	38	24.2%	50–99	40	25.5%	The USA	25	15.9%	Wholesaler	30	19.1%	Logistics manager	12	7.6%	Fashion and apparel	18	11.5%
50–100	26	16.6%	100–200	20	12.7%	Asia	4	2.5%	Distributor	14	8.9%	Operations manager	13	8.3%	Medical and healthcare	12	7.6%
> 100	82	52.2%	> 200	83	52.9%	Other	13	8.3%	Supplier	21	13.4%	Sales manager	3	1.9%	Automobile	11	7.0%
									Retailer	36	22.9%	Production manager	9	5.7%	Mechanic	7	4.5%
												Purchasing manager	2	1.3%	Energy	7	4.5%
												Procurement manager	8	5.1%	Furniture	6	3.8%
												Distribution manager	2	1.3%	E-commerce	5	3.2%
												Other	26	16.6%	Aerospace	4	2.5%
															Sport	4	2.5%
															Entertainment	4	2.5%
															Glass	3	1.9%
															Cement	3	1.9%
															Telecommunications	2	1.3%
															Luxury	2	1.3%
															Beauty and cosmetics	2	1.3%
															Electrical and electronics	2	1.3%
															Chemical	1	0.6%
															Other	30	19.1%
	157	1		157	1		157	1	157		1		157	1		157	1

(BP1), which indicates a firm's performance compared to competitors, the profits (BP2), which informs on a firm's capacity to generate economic value, the ROI (BP3), which signals a firm's capacity to recover investments through economic outcomes and the cost savings (BP4), highlighting the efficiency of the entire business. Finally, the items' environmental impact (BP5) and cost of energy (BP6) highlight the efficiency that a firm reached in terms of reduction of energy consumption and environmental impact.

According to the special issue by Verhoef *et al.* (2015), we develop an *ad hoc* scale to capture the firms' capacity to provide reverse omnichannel solutions. Therefore, the reverse omnichannel construct encloses the items depicting the options that firms make available to customers. The reverse omnichannel (O) construct encloses the items depicting the purchase options available to customers by the company. These include the possibility for firms to offer several return options, including returning the product either to the manufacturer (O1), or to the store where the product has been purchased or a store of the same chain (O2), or having the option to return to a specialized center for assistance (O3), or returning it online to a destination indicated during the purchase (O4) or returning the product to a locker (O5).

Regarding the construct Blockchain (B), being a new technology, research on scale developments is currently missing. Therefore, we propose hereby a measurement scale according to the ingredients emerged from the literature review with the purpose of exploring the practices that managers adopt when implementing this technology. One indicator that we include relates to working with blockchain developers (B1, e.g. Attaran and Gunasekaran, 2019; Ruzza *et al.*, 2022) to implement the technology within the current business model. Then, we also include items pertaining to a change in the standard way of managing agreements and transactions like the use of smart contracts (B2) (e.g. Rehman Khan *et al.*, 2021; De Giovanni, 2022) as well as the development of tokens (B3, e.g. Ruzza *et al.*, 2022; Farooque *et al.*, 2020) and the deployment of new exchanging platforms (B4, e.g. Attaran and Gunasekaran, 2019; van Hoek, 2019), resulting from the collaboration between partners and in the establishment of *ad hoc* training programs (B5, e.g. Attaran and Gunasekaran, 2019; van Hoek, 2019). Innovations are required to be in line with existing regulations, such as data protection and privacy rules (B6, e.g. van Hoek, 2019; Farooque *et al.*, 2020), and require combination with existing digital technologies for the full exploitation of their potential (B7, e.g. van Hoek, 2019).

The final items' list allows for the detection of the cross-loadings associated with each construct, as displayed in Table 3. Hereby, we can observe that some items (e.g. offering replacement products to consumers) have borderline loadings with values close to 0.6. However, the results of the 5,000 resamples indicate that these loadings (and weights) are significant at 0.05 and constitute important items in terms of content validity. According to Colicev *et al.* (2016), these items can then be retained. In contrast, we removed the item CLSC6 – offering cheap return options, since the loading was very low. This indicates that firms providing return options through the CLSC cannot guarantee the return service at a low cost. Furthermore, the option returning to a locker (O5) had a low loading, probably because the products to be returned via locker must have specific characteristics (e.g. size).

Table 4 displays the construct reliability indexes and shows that all of them are higher than the threshold 0.7. This highlights the strengths of our constructs in terms of internal consistency. Furthermore, we assess the convergent validity by evaluating the outer loadings and applying the average variance extracted (AVE) criterion. Our results, which are displayed in Table 4, demonstrate that the AVE for each construct takes values close the recommended threshold of 0.5 (Chin, 2010). Accordingly, the overall convergent validity can be considered as satisfactory.

Finally, the comparison between the AVE and the squared correlation among the constructs informs on the discriminant validity, which reflects the difference of a construct comparatively to the others. Furthermore, each item belonging to a certain construct should have a higher loading than the loadings associated to the other constructs. According to the developments illustrated in Tables 3 and 4, our model meets both of these criteria. In sum, we achieve satisfactory levels of internal consistency, convergent validity and discriminant validity. Consequently, the structural model can be subsequently analyzed.

4. Results and discussion

4.1 Hypothesis testing on the entire sample (Analysis 1)

This section provides the empirical results of the hypothesis testing by considering the entire sample; hence, no group is considered in this analysis. The general outcomes show a relative goodness-of-fit index of 0.808. All results are displayed in Table 5 in which we report the result "Supported" when a research hypothesis is empirically confirmed or "Not supported" otherwise. H1 is supported (*coef.* $= 0.234$ *and p-value* < 0.05), highlighting that the blockchain is an effective technology to successfully manage CLSC networks. In the same way, the blockchain enhances the proper management of reverse omnichannel solutions, as H2 yields positive and significant support (*coef.* $= 0.178$ *and p-value* < 0.05). H3 is also supported (*coef.* $= 0.364$ *and p-value* < 0.01), suggesting that investments in the blockchain are highly advantageous in achieving a more effective reverse omnichannel.

When it comes to the analysis of business performance, H4 is supported (*coef.* $= 0.131$ *and p-value* < 0.1), although with a significance threshold of 10%, highlighting that the use of the blockchain can induce a positive impact on business performance; even though, due to low

	CLSC	Reverse omnichannel	Business performance	Blockchain
Activating recycling operations	0.785			
Investing in refurbishing and remanufacturing of returned items	0.867			
Improving the information system to track returns	0.830			
Using specialized third-party logistics to acquire returns	0.506			
Offering replacement goods to consumers	0.617			
Return to the store		0.834		
Return online		0.838		
Return to a center		0.758		
Return to the manufacturer		0.693		
Market share			0.680	
Profits			0.718	
ROI			0.803	
Cost savings			0.728	
Cost for energy			0.742	
Environmental impact			0.631	
Consulting developers				0.819
Modifying the management of contracts and transactions				0.768
Tokens				0.679
New platforms				0.810
New training programs				0.701
Aligning the technology requirement with the regulations				0.815
Integrating blockchain technologies with other digital technologies				0.798

Table 3.
Summary of the cross-loadings

robustness, this result must be carefully examined on a case-by-case basis. In contrast, H5 is well-supported by our empirical results (*coef.* $= 0.443$ *and p-value* < 0.01), demonstrating that firms can effectively use the CLSC to increase their business performance. Finally, H6 finds no support (*coef.* $= -0.022$ *and p-value* > 0.1), indicating that the reverse omnichannel alone is not a fruitful practice to increase firms' business performance. Note that Table 4 does not report the indirect effects, since all were shown to be nonsignificant.

To check the robustness of our results, we make use of some descriptive variables to check whether the findings remain valid. Among those variables, we report in Table 6 the analysis on the number of employees. We use the category "Employees > 200" as a control group and verified that the results of the research hypotheses are in line with the results obtained on the whole sample and displayed in Table 5. Then, we compare the coefficients of the control group against the coefficients of the other categories, specifically, "Employees 100–200", "Employees 50–199" and "Employees < 50". The differences among the coefficients, named Δ coefficients, are most likely nonsignificant, highlighting the robustness of our findings. Similar analyses have been done with other categorical variables obtaining the same results.

4.2 Hypothesis testing in the collector-based value stream approach (Analysis 2)

In this section, we focus on the analysis of the collector incentives, that is, the incentives collectors receive as a counterpart to contributing and managing the collection of products. To carry out this analysis, which we refer to as *Analysis 2* and whose results are summarized in Table 7, we start by distinguishing between the sample of firms that offer collector incentives and firms that do not offer collector incentives. By using a dummy variable to distinguish the two groups, independent of consumer incentive *I* that is offered, we identify 94 firms offering collector incentives, namely, $Incentive_{IC}$, and 63 firms not offering collector incentives, namely, $Incentive_{\overline{IC}}$. Therefore, in all multigroup analyses that we carry out in this research, we display the result "Supported" if a hypothesis is confirmed or "Not supported" if it is not confirmed; furthermore, we report the result "Supported with a different sign" when the research hypothesis is empirically confirmed but with a reverse sign with respect to our expectations. For example, we hypothesize that a group performs higher scores than another group, while the empirical findings show an opposite result. Indeed, in all cases in which the multigroup analysis shows a support for the research hypothesis, the behavioral agency theory can help to explain the alignment of interests between the agents involved in the analysis.

Our empirical findings demonstrate that offering collector incentives enhances the impact of blockchain technology on the implementation and the management of CLSC systems (Δcoeff. = 0.425). In doing so, the CLSC shows a higher influence on the reverse omnichannel when collector incentives are offered (Δcoeff. = 0.510). In contrast, collector incentives do not grant any benefit in the relationship between the blockchain and reverse omnichannel

Table 4.
Inter-construct squared correlations and reliability measures

Index of composite reliability	Average variance extracted (AVE)	Construct	Blockchain	CLSC	Reverse omnichannel
0.887	0.595	*Blockchain*	1.000		
0.736	0.488	*CLSC*	0.234	1.000	
0.813	0.613	*Reverse Omnichannel*	0.406	0.264	1.000
0.812	0.517	*Business Performance*	0.225	0.468	0.147

(Δcoeff. = −0.265). Therefore, the behavioral agency theory explains the alignment of incentives among agents only partially.

Research hypotheses	Coefficients	Results
H1: The adoption of blockchain technology has a positive impact on the management of the CLSC system	0.234**	Supported
H2: The management of a CLSC system has a positive impact on the implementation of the reverse omnichannel	0.178**	Supported
H3: The adoption of blockchain technology has a higher positive impact on the implementation of the reverse omnichannel	0.364***	Supported
H4: The implementation of blockchain technology has a positive impact on a firm's business performance	0.131*	Supported
H5: The management of the CLSC has a higher positive impact on a firm's business performance	0.443***	Supported
H6: The implementation of reverse omnichannel options has a higher positive impact on a firm's business performance	*−0.022*#	Not supported

Note(s): ****p* = value < 0.01; ***p* = value < 0.05; **p* = value < 0.1; # italic values are not significant

Table 5.
Results of the research hypotheses

Research hypotheses	Coefficients for "Employees >200 "	Results	Δ coefficients with "Employees > 200" Employees 100–200	Employees 50–99	Employees < 50
H1: The adoption of blockchain technology has a positive impact on the management of the CLSC system	0.288**	Supported	0.511*	*0.086*	*0.309*
H2: The management of a CLSC system has a positive impact on the implementation of the reverse omnichannel	0.167*	Supported	*0.558*	*0.118*	*0.052*
H3: The adoption of blockchain technology has a higher positive impact on the implementation of the reverse omnichannel	0.270**	Supported	*0.354*	*0.479*	*0.527*
H4: The implementation of blockchain technology has a positive impact on a firm's business performance	0.168*	Supported	*0.174*	*0.476*	*0.496*
H5: The management of the CLSC has a higher positive impact on a firm's business performance	0.313***	Supported	*0.103*	*0.046*	*0.365*
H6: The implementation of reverse omnichannel options has a higher positive impact on a firm's business performance	*−0.026*#	Not supported	*0.316*	*0.096*	*0.205*

Note(s): ****p* = value < 0.01; ***p* = value < 0.05; **p* = value < 0.1; # italic values are not significant

Table 6.
Robustness check with respect to the control variable "Employees"

This is also confirmed when we analyze the impact on the business performance; offering collector incentives does not allow either the adoption of blockchain technology or the implementation of CLSC systems to exert a higher impact on business performance. The empirical results linked to both the blockchain (Δcoeff. = 0.111) and the CLSC (Δcoeff. = 0.032) show nonsignificant improvements in business performance. Finally, collector incentives can yield a higher influence on business performance through the implementation and management of the reverse omnichannel (Δcoeff. = 0.246). However, this effect is weak (given that it is significant with a *p-value of* < 0.1) and must be carefully evaluated by firms.

4.3 Hypothesis testing in the consumer-based value stream approach (Analysis 3)

In this section, we explore the effects of consumer incentives within our research framework. We analyze the incentives that consumers receive when contributing to the collection of products. To pursue our research target, which is developed as *Analysis 3* and displayed in Table 8, we begin by distinguishing between the sample of firms that offer consumer incentives and firms that do not. We use a dummy variable to distinguish the two groups. Independent of the collector incentive *J* that is offered, we identify 91 firms offering consumer incentives, namely, $Incentive_{CJ}$, and 66 firms not offering consumer incentives, namely, $Incentive_{\overline{C}J}$.

Our empirical analysis reveals that consumer incentives do not improve the impact that blockchain technology exerts in the implementation and management of CLSCs

Research hypotheses	Coefficients for firms offering collector incentives ($Incentive_{IC}$)	Coefficients for firms not offering collector incentives ($Incentive_{I\overline{C}}$)	Results
When offering $Incentive_{IC}$ rather than $Incentive_{I\overline{C}}$, it results that			
H1a: The adoption of blockchain technology has a higher positive impact on the management of the CLSC system	0.346***	*−0.079*[#]	Supported
H2a: The management of a CLSC system has a higher positive impact on the implementation of reverse omnichannel	0.418***	*−0.092*	Supported
H3a: The adoption of blockchain technology has a higher positive impact on the implementation of reverse omnichannel	0.309***	0.574***	Supported
H4a: The implementation of blockchain technology has a positive impact on a firm's business performance	0.232**	0.121*	Not supported
H5a: The management of the CLSC has a higher positive impact on a firm's business performance	0.413***	0.445***	Not supported
H6a: The implementation of reverse omnichannel options has a higher positive impact on a firm's business performance	0.201*	*−0.045*	Supported

Note(s): ***p = value < 0.01; **p = value < 0.05; *p = value < 0.1; [#] italic values are not significant

Table 7. Results of the multigroup analysis based on collector incentives

(Δcoeff. = 0.067). In contrast, CLSC systems can benefit from the presence of consumer incentives to activate and exploit the reverse omnichannel options (Δcoeff. = 0.369). Interestingly, the empirical results demonstrate that consumer incentives entail a decreasing impact of the blockchain on both the reverse omnichannel and business performance. Specifically, when consumer incentives are offered, blockchain technology has a significantly lower impact on the reverse omnichannel (Δcoeff. = 0.253). Furthermore, the presence of consumer incentives causes the blockchain to lower business performance (Δcoeff. = −0.130). These results demonstrate an incompatibility between the blockchain and consumer incentives. Finally, consumer incentives do not improve the firms' business performance, either through the CLSC (Δcoeff. = 0.056) or through the reverse omnichannel (Δcoeff. = −0.049). Interestingly, in all cases in which the results are confirmed with a different sign, the behavioral agency theory is not useful to explain our results and to align the consumers' behaviors to the firms' targets. This is probably given by the difficulties that firms encounter to adjust and modify the consumers' behaviors in managing waste and contributing to CE targets.

4.4 Hypothesis testing in the value-stream approach (Analysis 4)

After exploring the isolated effects of collector and consumer incentives in *Analysis 2* and *Analysis 3*, respectively, we now explore the effects of the simultaneous presence of consumer and collector incentives in *Analysis 4,* which is displayed in Table 9. We distinguish the sample of firms that adopt a value-stream approach by offering both incentives, which is given by $Incentive_{CC}$. By considering all possible combinations of groups, the sample is composed of 62 firms offering $Incentive_{CC}$. The remaining sample is composed of 30 firms offering $Incentive_{\overline{C}C}$, 34 firms offering $Incentive_{C\overline{C}}$ and 31 firms disregarding any type of incentives, then $Incentive_{\overline{CC}}$ and implementing a waste-stream approach. Table 7 displays the results by focusing on the hypotheses that are supported in order to focus on the relevant outcomes. The empirical findings reveal that adopting a value-stream approach always boosts the effect of blockchain technology on the implementation and management of CLSCs (see the results of H1a). In contrast, higher effects of blockchain on the management of the reverse omnichannel can occur only when collector incentives are not offered. This result remains valid also in terms of business performance, making a value-stream less appealing in this sense and the behavioral agency theory not being fully applicable. However, the value-stream approach is preferable to a waste-stream approach when firms seek to acquire competencies in the area of reverse omnichannel by exploiting their capabilities in the CLSC and reinforce them through the blockchain.

4.5 Hypothesis testing in the waste-stream approach (Analysis 5)

In this section, we compare the outcomes in both the partially active return approaches (consumer-based and collector-based) to the waste-stream approach. Note that the value-stream approach and the waste-stream approach have already been compared in *Analysis 4*. *Analysis 5,* which is reported in Table 10, finalizes that analysis by comparing the partial value-stream approaches to the waste-stream approach. The empirical analysis demonstrates that a partially active return approach always guarantees an improvement of the CE, which is exemplified by the higher impact of the CLSC on the management of the reverse omnichannel in comparison to a waste-stream approach. Overall, with respect to the waste-stream approach, the collector-based value stream approach boosts the impact of the blockchain on the reverse omnichannel (see the results of H3a), while the consumer-based value stream approach boosts the impact of the blockchain on the implementation and management of the CLSC (see the results of H1a). Finally, in comparison to the waste-stream approach, a consumer-based value stream approach does not guarantee an improvement in business performance through the

Research hypotheses	Coefficients for firms offering consumer incentives ($Incentive_{CJ}$)	Coefficients for firms not offering consumer incentives ($Incentive_{\overline{CJ}}$)	Results
When offering $Incentive_{CJ}$ rather than $Incentive_{\overline{CJ}}$, it results the following:			
H1a: The adoption of blockchain technology has a higher positive impact on the management of the CLSC system	0.264**	0.197**	Not supported
H2a: The management of a CLSC system has a higher positive impact on the implementation of the reverse omnichannel	0.315**	*0.054*	Supported
H3a: The adoption of blockchain technology has a higher positive impact on the implementation of the reverse omnichannel	0.249**	0.502***	Supported with reverse sign
H4a: The implementation of blockchain technology has a positive impact on the business performance	*0.057*	0.187*	Supported with reverse sign
H5a: The management of the CLSC has a higher positive impact on the business performance	0.440***	0.386***	Not supported
H6a: The implementation of reverse omnichannel options has a higher positive impact on the business performance	*0.012*	*0.061*	Not supported

Note(s): ***p = value < 0.01; **p = value < 0.05; *p = value < 0.1; # italic values are not significant

Table 8. Results of the multigroup analysis based on consumer incentives

implementation and management of the reverse omnichannel (see the results of H6a). However, both incentive mechanisms increase the effectiveness of CE systems (see the results of H2a). These results highlight the idea that the behavioral agency theory applies only in some circumstances, and its usage needs to be properly contextualized.

5. Discussion and managerial insights

5.1 Managerial insights from Analysis 1

When considering the entire sample (*Analysis 1*), our findings demonstrate that the implementation of blockchain technology has positive effects on the management of both the CLSC and the reverse omnichannel. This is in line with Rehman Kan *et al.* (2021), who find a positive association between the blockchain and CLSC. We enrich this result by also analyzing the CE from a reverse omnichannel point of view and, then, increasing the body of knowledge in this domain. Interestingly, the impact of the blockchain on the reverse omnichannel is higher than its impact on the CLSC. This is primarily linked to the challenges that firms face in managing heterogeneous omnichannel options, whose integration can be highly difficult due to their connections with external sources. Indeed, the manner in which the CLSC is studied in this research (e.g. remanufacturing and recycling activities) makes it an internal matter. Consequently, the blockchain turns out to have a lower impact. In fact, as mentioned previously, blockchain technology represents a potential connector between a firm's physical world and the digital world. For example, hardware oracles can be connected to the blockchain and register the single actions that a truck driver performs (e.g. the

Table 9. Results of the multi-group analysis based on the value-stream approach

Research hypotheses	Firms offering incentives for both collectors and consumers (value-stream approach)	Firms offering other incentives	Results
When offering $Incentive_{CC}$ rather than $Incentive_{\overline{C}C}$, it results the following:			
H1a: The adoption of blockchain technology has a higher positive impact on the management of the CLSC system	0.512***	0.305**	Supported
When offering $Incentive_{CC}$ rather than $Incentive_{C\overline{C}}$, it results the following:			
H1a: The adoption of blockchain technology has a higher positive impact on the management of the CLSC system	0.512***	*−0.031*	Supported
H3a: The adoption of blockchain technology has a higher positive impact on the implementation of the reverse omnichannel	0.274**	0.657***	Supported with reverse sign
H5a: The management of the CLSC has a higher positive impact on the business performance	0.322***	0.625***	Supported with reverse sign
H6a: The implementation of reverse omnichannel options has a higher positive impact on the business performance	0.164*	*−0.101*	Supported
When offering $Incentive_{CC}$ rather than $Incentive_{\overline{CC}}$, it results the following:			
H1a: The adoption of blockchain technology has a higher positive impact on the management of the CLSC system	0.512***	*0.102*	Supported
H2a: The management of a CLSC system has a higher positive impact on the implementation of the reverse omnichannel	0.298**	−0.325***	Supported
H3a: The adoption of blockchain technology has a higher positive impact on the implementation of the reverse omnichannel	0.274**	0.726***	Supported with reverse sign

Note(s): ***p = value < 0.01; **p = value < 0.05; *p = value < 0.1; # italic values are not significant

frequency and the length of a truck door opening when transporting frozen goods), which might have a direct connection with the product quality (e.g. frequent and long truck door openings can interrupt the frozen chain). Therefore, the blockchain may be more effective when applied to external processes when compared to its use for internal purposes.

Our results reveal that the CLSC has a significant influence on the reverse omnichannel. Accordingly, the presence of an effective CLSC, considered as a system through which goods can be collected and treated in several ways to give them a second life, suggests that firms should activate various return options by also allowing collectors to return goods using omnichannel options. Therefore, when firms have an effective CLSC in place, they can rely on the implementation of a reverse omnichannel to strengthen their collection capabilities. The

Research hypotheses	Firms offering incentives	Firms not offering incentives (waste-stream approach)	Results
When offering $Incentive_{\overline{C}C}$ rather than $Incentive_{\overline{CC}}$, it results the following:			
H2a: The management of a CLSC system has a higher positive impact on the implementation of the reverse omnichannel	0.330***	−0.325***	Supported
H3a: The adoption of blockchain technology has a higher positive impact on the implementation of the reverse omnichannel	0.301**	0.726***	Supported with reverse sign
When offering $Incentive_{C\overline{C}}$ rather than $Incentive_{\overline{CC}}$, it results the following:			
H1a: The adoption of blockchain technology has a higher positive impact on the management of the CLSC system	0.312***	*0.102*	Supported
H2a: The management of a CLSC system has a higher positive impact on the implementation of the reverse omnichannel	0.259**	−0.325***	Supported
H6a: The implementation of the reverse omnichannel options has a higher positive impact on the business performance	−0.402**	*−0.014*	Supported with a reverse sign

Note(s): ***p = value < 0.01; **p = value < 0.05; *p = value < 0.1; # italic values are not significant

Table 10.
Results of the multigroup analysis based on the waste-stream approach

empirical result that we obtain corroborates the body of knowledge in the literature since the connection between the CLSC and reverse omnichannel has been investigated through either game theory approaches (e.g. Ma *et al.*, 2013) or by clinical case studies (e.g. Zalando and Apple). The results of this study offer a genuine contribution to suggest the implementation of CE systems as being composed of both operational and service components, given by the CLSC and reverse omnichannel, respectively.

Regarding business performance, our empirical results demonstrate that the implementation of a reverse omnichannel does not influence business performance, either positively or negatively. Therefore, offering seamless experiences through omnichannel solutions in the context of CE does not contribute to business performance. These results are in line with Pezzini (2020), according to which the difficulties in integrating all options in an omnichannel system cause business performance to suffer in many instances. This is in fact confirmed when dealing with the reverse omnichannel, as the handling returns necessitate atypical procedures and new competencies upon which firms must rely.

When it comes to the blockchain, our findings reveal that this technology's support in terms of business performance is weak. From a managerial point of view, firms investing in the blockchain should be aware of the uncertain association with business performance. This result contrasts with the empirical studies by Ko *et al.* (2018), which demonstrate the positive links between the blockchain and performance. Rather, our results are aligned to studies such as those of Kouhizadeh *et al.* (2020), Naclerio and De Giovanni (2022), and van Hoek (2019), which highlight the barriers, the difficulties and the tensions linked to the adoption of blockchain technology, which results in a nonclear implication for business performance, especially within the CE framework.

Finally, firms can easily improve business performance by implementing and effectively managing the CLSC. This is in line with other research in the field that sponsors the CLSC to improve performance (e.g. Rehman Kan *et al.*, 2021; Shaharudin *et al.*, 2017). Considering the measures we used for the CLSC, firms should invest in CLSC operations, such as refurbishing, remanufacturing and recycling, to activate a second life, as well as in CLSC service operations through information systems, specialized third-party logistics and replacement goods, to ensure high business performance.

5.2 Managerial insights from Analysis 2

When investigating collector incentives, our findings reveal the possible trade-offs emerging between the CLSC and the reverse omnichannel with respect to the blockchain, allowing us to proffer original managerial insights. To our knowledge, this is the first empirical study analyzing how collector incentives impact on the blockchain's effectiveness. Consistent with our expectations, offering collector incentives translates into a higher impact of the blockchain on the CLSC. Hence, when collectors are actively engaged, the blockchain becomes more effective. This result is clearly aligned with smart contracts embedded in the blockchain. The collectors receive incentives only when they successfully perform the collection; hence, the smart contracts inside the blockchain ensure the alignment of both firms and collectors in the management of CLSC activities. Therefore, while the literature of the CLSC focuses on how to engage collectors through traditional systems (e.g. per-return incentive as in Savaskan *et al.* (2004)), our empirical analysis reveals that the use of the blockchain and the related smart contracts can definitely be helpful and supportive to move the level of engagement to a higher level.

In contrast, when firms provide collector incentives, the blockchain has a lower impact on the implementation and management of reverse omnichannel systems. This finding is reversed with respect to what we expected and is probably a result of the nature of collector incentives with respect to the nature of the reverse omnichannel. The former are given to collectors, while the latter are returning options offered to consumers. This result is in line with the literature of consumers' engagement in CE activities (Kuah and Wang, 2020), which highlights the difficulties in aligning the consumers' behavior to CE targets. Furthermore, collectors are not necessarily an integral component of the business model and require convincing incentives to become partners. In contrast, omnichannel solutions are already integrated within the entire business model, and further collector incentives would simply be less effective. In summary, when firms seek to implement a collector incentive, they should evaluate which portion of business they wish to improve. We discover a trade-off between the CLSC and the reverse omnichannel: when collectors' incentives are present (absent), the impact of the blockchain on the CLSC becomes more (less) important, while the reverse omnichannel becomes less (more) effective. Hence, firms should provide (avoid) collector incentives if they seek to reinforce the effects of the bblockchain on the CLSC (the reverse omnichannel). However, when firms seek to integrate collectors to a greater extent within the omnichannel strategies; granting collector incentives is a fruitful driver to achieve that target.

Finally, collector incentives are fully ineffective in improving a firm's business performance through the blockchain and CLSC. This is probably linked to the economic trade-off that is raised when providing collector incentives: they imply a pure outflow of economic resources that is not counterbalanced by appealing and immediate economic outcomes. In contrast, we observe an important improvement in the omnichannel on business performance when incentives are provided. This is the only way for firms to improve business outcomes by adopting a collector-based, value-stream approach.

5.3 Managerial insights on consumer incentives (Analysis 3)

In this section, we derive some managerial insights for firms when aiming to offer consumer incentives. To our knowledge, the results and the intuitions derived here are novel as this is the sole empirical study analyzing how consumer incentives impact on the blockchain's effectiveness on CE systems and the related influence on performance. Since these incentives are directly given to consumers, the industrial component of a CE is only marginally influenced. Our results demonstrate that blockchain technology does not become more effective for the CLSC when consumer incentives are offered. This result complements the findings by Kuah and Wang (2020), according to which consumers' engagement in CE activities is challenging and uncertain, even in presence of blockchain technology. Hence, firms investing and implementing CLSC systems should be aware that consumer incentives do not unlock the industrial potential of the blockchain. This is most likely explained by the main functionalities of the blockchain, whose smart contracts are devised for partners and suppliers rather than for consumers. This clearly indicates that the current level of immaturity of such technology in the adoption of human oracles prevents the full use and exploitation of the blockchain.

We observe that consumer incentives discourage firms from adopting the blockchain to improve and manage the reverse omnichannel. This result definitely depends on the type of information the blockchain records when goods are returned through a reverse omnichannel. When consumers approach any return option via an omnichannel, the collecting system records various information, such as the products' status, conditions and residual value. Hence, the blockchain records information about how consumers have used the product and associates a single return to a single consumer through rewards generated in the form of fungible and/or nonfungible tokens. Therefore, our results, which also remain valid for business performance, are justified by consumers' cultural barriers and privacy protection wishes, which limit the diffusion of blockchain technology in these instances.

In contrast, consumer incentives work very well in enhancing the effectiveness of the CLSC for the reverse omnichannel. In other words, firms implementing a successful CLSC should pursue a reverse omnichannel to engage consumers in returning end-of-use and end-of-life products. Our results suggest that firms should offer consumer incentives when aiming to further reinforce such engagement. This result confirms the theoretical research by Genc and De Giovanni (2017), according to which the CLSC options as well as the related returning activities can work out only when consumers receive adequate incentives and find the whole collecting infrastructure supportive and efficient.

Finally, providing consumer incentives has a nonsignificant impact on performance. Thus, firms should be aware that providing consumer incentives does not translate into higher business performance through CE systems. If firms aim to increase their business performance, consumer incentives will not be an effective practice to boost the effectiveness of the CE systems. Firms are advised to engineer other types of incentives and mechanisms, or to evaluate the benefits of consumer incentives stemming from blockchain and CE systems.

5.4 Managerial insights on active return approach (Analysis 4)

In this section, we analyze the benefits firms can obtain when taking an active return approach. The latter consists of simultaneously offering both consumer and collector incentives. According to our results, we can suggest that firms should focus on collector incentives to unlock the effectiveness of the blockchain on CE. In fact, any time consumer incentives play a role, the blockchain turns out to be ineffective in reinforcing both the CLSC network and systems as well as the reverse omnichannel. This suggests that CE is a business-to-business challenge and requires coordination at the firm level. Hence, collector incentives are effective for improving CE systems, while consumer incentives have an opposite effect.

Under the CE system, firms should be aware that an effective CLSC engages consumers in returning through reverse omnichannel options. Our results demonstrate that an active return approach is advisable to further engage consumers in the return process. That is, the presence of a dual incentive (collector and consumer incentives) results in an improved CE system. This result is in line with the research using game theory approaches to analyze active return approaches and their benefits (see De Giovanni and Zaccour (2022) for a comprehensive overview). However, this is the first study offering an empirical support on the benefits that active return approaches grant to CE systems. Our result is driven by the possible complexity that arises when dealing with increasing feedstock induced by multiple sources, specifically, industrial returns from collectors and consumer returns from consumers.

However, this result holds true in the analysis of business performance. In fact, our results demonstrate that firms can enjoy a few improvements in business performance attributable to the presence of an active return approach. Such improvements are linked to the higher benefits induced by the CLSC and/or reverse omnichannel to business performance but are never linked to blockchain technology, whose impact remains weak, even in the presence of active return approaches. Therefore, an active return approach can guarantee an improvement in business performance only in a few cases, with collector incentives playing a decisive role in unlocking the potential of both the CLSC and reverse omnichannel.

5.5 Managerial insights on the waste-stream approach (Analysis 5)

Analysis 5 searches for the adoption of partially active return approaches, that is, either a consumer-based or collector-based value stream approach in comparison to the waste-stream approach. This analysis allows firms to identify the possible benefits obtainable when moving from a waste-stream approach to a partial value-stream approach.

In general, the adoption of one mechanism only offers marginal benefits to firms. Independent of the partial value-stream approach undertaken, firms can improve the management of the CE system, which is exemplified by higher reverse omnichannel capabilities and options guaranteed through the operational capabilities acquired in the CLSC. In contrast, none of the incentive mechanisms ensures an improvement of the entire CE system through the blockchain. In fact, in comparison to a waste-stream approach, the blockchain can entail higher effects to the reverse omnichannel when firms adopt a collector incentive, while the blockchain can entail higher effects to the CLSC system when firms adopt a consumer incentive. Therefore, firms must evaluate the outcome they wish to achieve (higher operational capabilities in the CLSC or higher service capabilities in the reverse omnichannel) before deciding on the active return approach to be put into place. Finally, it is difficult for firms to increase business performance by only offering one incentive type.

6. Theoretical contributions

This study bridges three research areas, namely, blockchain technology, CE systems and incentive mechanisms, and, as mentioned in the introduction, focuses on three targets. The first target consists of studying CE systems composed of two major pillars: the CLSC and reverse omnichannel. The dual system enriches the theoretical background in CE, since its simultaneous implementation creates a comprehensive framework for successfully managing CE activities. On the one hand, the CLSC embeds the hard and operational sides of a CE system, including the traditional operational capabilities needed for collecting, remanufacturing, recycling and refurbishing. Therefore, the CLSC deals with the industrial concerns linked to CE. On the other hand, the reverse omnichannel embeds the soft and service sides of a CE system by offering seamless experiences to consumers who wish to return goods. The reverse omnichannel includes capabilities linked to collecting services, which can be pursued through a variety of options, such as returns to stores, returns online, returns to a center and returns to the manufacturer. Hence, the reverse omnichannel deals with service concerns of CE and seeks to increase the feedstock to feed the operations in a CLSC system. Including the service options offered to consumers through a reverse omnichannel within CE systems represents an important theoretical development thought that the literature has always focused on the CLSC (e.g. Rehman Khan *et al.*, 2021; Shaharudin *et al.*, 2017; French and LaForge, 2006).

According to the proposed theoretical framework, modern CE systems include both hard and soft ingredients, which are clearly connected and influence each other. When the reverse omnichannel is not offered, the CLSC still ensures circularity while working with a feedstock collected through traditional systems. In contrast, when the CLSC is not present, firms handle return services and accumulate feedstock through the reverse omnichannel without having the operational capabilities to properly treat it. Since the latter is a nonfeasible option from an operational perspective as well as an economic perspective, our theoretical framework offers a genuine recommendation to consider the CLSC as an antecedent of reverse omnichannel and CE systems composed of both simultaneously.

Within the theoretical framework, our second contribution links to the impact blockchain technology has on CE systems. The modern business models and SCs look at the blockchain as a technology to guarantee transparency, visibility and traceability. These properties can considerably help CE systems in mitigating some historical challenges associated with CE outcomes. For example, how can consumers ensure trust when buying a refurbished good? How can they verify the sources of the recycled materials? How can they determine that secondhand goods have passed all quality controls before being sold? These and many other concerns, which have emerged from the literature (e.g. Edbring *et al.*, 2016), can be easily overcome by adopting blockchain technology (Bekrar *et al.*, 2021). In fact, the blockchain platform records all information linked to the collected goods, as well as all operational activities carried out to ensure a second life and proper treatment. Our theoretical framework develops around such relationships, in which the blockchain mitigates both the risks and the lack of information on CLSC activities, while enhancing confidence and trust regarding CE systems and their outcomes.

The aforementioned benefits of transparency, visibility and traceability induced by blockchain technology also impact the success of the reverse omnichannel. The use of the blockchain can guarantee trustworthy information in several aspects of the return process, such as: the status of returned goods, the position over the SC and across all channels, the moment it is sent back to consumers and how it is managed during the entire return process. Our theoretical contributions develop in this direction: The blockchain can ensure trust and enhance confidence regarding product collection, as well as when it is managed through a set of reverse omnichannel options.

Finally, our theoretical framework makes a third contribution to the literature by building upon the concept of incentive mechanisms, which are common to both blockchain technology and CE systems fields. The incentive mechanisms that are generally implemented on a blockchain and that activate the smart contracts can be explained by the behavioral agency theory by Peper and Gore (2015). The latter makes use of the principal–agent principles to pursue efficient and effective relationships by providing engaging contracts, developing motivations and above all, focusing on performance achievements. The principal seeks to motivate the agents to perform as the principal wishes by developing and executing compensation schemes. This is exactly the idea of the smart contracts embedded in blockchain technologies, which automatically execute incentive mechanisms as far as the contractor achieves some performance levels (De Giovanni, 2022). Farooque *et al.* (2020) highlights the lack of rewards and encouragement programs as one of the main barriers linked to the adoption of blockchain technology. In fact, it is well documented that in order to activate the smart contracts, smart clauses embedded in the blockchain pursue performance alignment between all parties involved in the contracts (Mastos *et al.*, 2021). Therefore, each party should respect the contract terms to allow the smart contract to execute the payment. For example, a smart contract contains a clause according to which a hauler should finalize a delivery by noon. If the delivery is done by noon, the smart clause executes the payment to the hauler; if the delivery is done with some delays, the smart clause executes the payment of a reduced amount that will be proportional to the amplitude of the delay (De Giovanni, 2022). Therefore, the smart contracts embedded in the blockchain activate incentives for the parties to perform as written in the contracts.

The issue of incentive mechanisms is also very popular within the CE framework, in which firms still need to understand how to acquire an appropriate feedstock through take-back programs. In this regard, firms can adopt either a passive (or waste-stream) approach to collection, or an active return (value-stream) approach to collection. In the former, no effort is made to increase the feedstock, which is accumulated passively, that is, by waiting for society at large to contribute to the collection on a voluntary basis. In contrast, firms can adopt numerous take-back programs to actively engage society in the collection by providing incentives for consumers and/or collectors.

Within this framework we develop our theoretical contributions. The implementation of both blockchain and CE systems requires a deep analysis of the incentive mechanisms to be put into place. On the one hand, the incentives activate the smart contracts inside the blockchain and enforce behavior and actions. On the other hand, the incentives enable a CE system to move from a cost-centered (waste-stream approach) to a profit-centered (value-stream approach) approach and actively engage both consumers and collectors. Therefore, only the proper design of incentive mechanisms unlocks the full potential of the blockchain and guarantees successful CE systems.

7. Conclusions

This research analyzes the implications that blockchain technology exerts on CE systems, which are composed of both the CLSC and reverse omnichannel options. Considering blockchain's worldwide expansion and its multiple applications, this study seeks to investigate how blockchain contributes within the CE domain and the possible benefits that firms gain in terms of business performance. Furthermore, the study bridges the fields of blockchain and CE systems by discussing possible implications in terms of incentive mechanisms, whose development is theoretically supported by the behavioral agency theory (Peper and Gore, 2015). The latter play a key role in activating smart contracts in the blockchain, while they also make it possible for CE systems to shift from a passive return (waste-stream) approach to an active return (value-stream) approach.

Our findings reveal that the blockchain is an effective technology to enhance the operational capabilities embedded in the CLSC, as well as the service capabilities embedded in the reverse omnichannel. In implementing the blockchain, all CLSC operations become transparent and secure, with the result of gaining confidence and trust in CLSC outcomes. Specifically, the blockchain ensures better acceptance among consumers when purchasing refurbished goods, and among firms when using recycled materials. Similarly, when implementing the blockchain, the reverse omnichannel can ensure visibility and traceability, offering consumers high value in terms of return services. Regarding the business performance, our findings demonstrate that the reverse omnichannel is not effective at all for improving business performance, while the blockchain has a weak significant impact and a marginal amplitude. In contrast, the CLSC has a significant and considerable impact on business performance. These outcomes indicate that firms can implement successful CE systems by focusing on the operational capabilities embedded in the CLSC. In fact, the blockchain only offers a weak contribution to business performance, while the service capabilities embedded in the reverse omnichannel do not guarantee any sufficient improvement in that direction.

Finally, we analyze the impact of incentives by focusing on incentives offered to consumers, namely, *consumer incentive*, and incentives offered to collectors, namely, *collector incentives*. We then verify how moving from a waste-stream approach (no incentive is granted) to a value-stream approach (incentives for both consumers and collectors) influences the overall results and offers genuine guidance regarding how firms should design incentives when implementing the blockchain within CE systems. The analysis of incentives is supported by the behavioral agency theory, which sponsors the alignment of the principal's interests with the agents' interests through compensation schemes, goal settings, motivations to score high performance according to the agents' abilities and opportunities and contractual incentives. We discover that, when the behavioral agency theory is used in the CE framework and applied through blockchain technology, it is only partially applicable. In fact, our findings reveal that offering incentives to collectors pushes firms to focus on CLSC strategies and abandon the reverse omnichannel. This most likely depends on integration issues, since collectors must be incentivized to become active components of the CE system. However, collectors' incentives do not change the main findings in terms of business performance. Therefore, firms should always look at the operational capabilities included in the CLSC as the main driver to pursue satisfactory business outcomes, while the blockchain remains a weak driver. Interestingly, the collector incentives activate the power of the reverse omnichannel to increase business performance, rendering a collector-based value stream approach successful from a business perspective.

When consumer incentives are offered, the industrial benefits that the blockchain is employed to provide to the CLSC are lost. This probably happens because such incentives possess a consumer-based nature, while the CLSC includes industrial concerns. In contrast, these incentives are very effective in improving, reinforcing and integrating the CE systems. We observe interesting effects induced by the blockchain, which has a higher amplitude on the omnichannel and performance when consumer incentives are not offered. This is probably due to the cultural barriers of using the blockchain, as consumers are asked to record information such as product usage or its residual value. These pieces of information can be directly linked to consumers' privacy, inducing high levels of reluctance when incentives are offered.

Finally, the adoption of an active return approach can provide important enhancements to business performance, even though our findings reveal that collector incentives activate the potential of the blockchain, while consumer incentives activate the potential of the CLSC and the reverse omnichannel. However, we observe that the joint effects of incentives give negligible impact on business performance.

This research is not free of limitations, which are listed herein to increase interest in the topic and inspire future research in the same domain. This paper focuses on the analysis of the blockchain as the sole digital technology to improve both the CLSC and the reverse omnichannel. Other technologies belonging to Industry 4.0 can surely have a different effect on the findings (Rosa *et al.*, 2020). For example, the use of recycled materials obtained by closing the loop can be used as a composite material for 3D printers. The use of Big Data to optimize the forward and reverse flows of the reverse omnichannel can have a considerably positive impact on the effectiveness of the CLSC. Furthermore, the use of Internet of Things (IoT) systems is vital to capture information around the eco-system and record on the blockchain. Note that we shape the research assuming that the CLSC influences the reverse omnichannel; this assumption is strictly linked to the adoption of the blockchain, which records all operational-based information in the CLSC and allows one to trace and enrich it through the reverse omnichannel afterward. Future developments in the same area can assume and discuss an inverse relationship between the CLSC and reverse omnichannel, which can be justified either when using different digital technologies to assess their link or when contextualizing it in an alternative domain. Furthermore, future work should also investigate some barriers linked to the adoption of digital technologies, such as structural constraints attributable to system rigidity, as well as cultural obstacles linked to well-established modus operandi (Son *et al.*, 2021). It would be interesting to collect longitudinal data and evaluate the findings of this research through a dynamic analysis. Finally, other methodologies can help to extrapolate additional information, such as the use of decision trees to identify the set of CLSC actions that influence business performance the most, or logistics models that drive firms to shift from one incentive type to another.

References

Abeyratne, S.A. and Monfared, R.P. (2016), "Blockchain ready manufacturing supply chain using distributed ledger", *International Journal of Research in Engineering and Technology*, Vol. 5 No. 9, pp. 1-10.

Agyabeng-Mensah, Y., Ahenkorah, E., Afum, E., Dacosta, E. and Tian, Z. (2020), "Green warehousing, logistics optimization, social values and ethics and economic performance: the role of supply chain sustainability", *The International Journal of Logistics Management*, Vol. 31 No. 3, pp. 549-574.

Ahsan, K. and Rahman, S. (2022), "A systematic review of e-tail product returns and an agenda for future research", *Industrial Management and Data Systems*, Vol. 122 No. 1, pp. 137-166.

Attaran, M. and Gunasekaran, A. (2019), "Implementing blockchain in your enterprise", *Applications of Blockchain Technology in Business*, Springer, Cham, pp. 95-102.

Bai, C. and Sarkis, J. (2020), "A supply chain transparency and sustainability technology appraisal model for blockchain technology", *International Journal of Production Research*, Vol. 58 No. 7, pp. 2142-2162.

Bekrar, A., El Cadi, A.A., Todosijevic, R. and Sarkis, J. (2021), "Digitalizing the closing-of-the-loop for supply chains: a transportation and blockchain perspective", *Sustainability*, Vol. 13 No. 5, p. 2895.

Bell, D.R., Gallino, S. and Moreno, A. (2014), "How to win in an omnichannel world", *MIT Sloan Management Review*, Vol. 56 No. 1, pp. 45-51.

Bernon, M., Cullen, J. and Gorst, J. (2016), "Online retail returns management: integration within an omni-channel distribution context", *International Journal of Physical Distribution and Logistics Management*, Vol. 46 Nos 6/7, pp. 584-605.

Bhatia, M.S. and Kumar Srivastava, R. (2019), "Antecedents of implementation success in closed-loop supply chain: an empirical investigation", *International Journal of Production Research*, Vol. 57 No. 23, pp. 7344-7360.

Biswas, D., Jalali, H., Ansaripoor, A.H. and De Giovanni, P. (2022), "Traceability vs. sustainability in supply chains: the implications of blockchain", *European Journal of Operational Research*, in press. doi: 10.1016/j.ejor.2022.05.034.

Blackburn, J.D., Guide, V.D.R., Jr, Souza, G.C. and Van Wassenhove, L.N. (2004), "Reverse supply chains for commercial returns", *California Management Review*, Vol. 46 No. 2, pp. 6-22.

Böckel, A., Nuzum, A.K. and Weissbrod, I. (2021), "Blockchain for the circular economy: analysis of the research-practice gap", *Sustainable Production and Consumption*, Vol. 25, pp. 525-539.

Brynjolfsson, E., Hu, Y.J. and Rahman, M.S. (2013), "Competing in the age of omnichannel retailing", *MIT Sloan Management Review*, pp. 1-7.

Capgemini. (2018), "Does blockchain hold the key to a new age of supply chain transparency and trust? How organizations have moved from blockchain hype to reality".

Cardinali, P.G. and De Giovanni, P. (2022), "Responsible digitalization through digital technologies and green practices", *Corporate Social Responsibility and Environmental Management*. doi: 10.1002/csr.2249.

Chang, Y., Iakovou, E. and Shi, W. (2020), "Blockchain in global supply chains and cross border trade: a critical synthesis of the state-of-the-art, challenges and opportunities", *International Journal of Production Research*, Vol. 58 No. 7, pp. 2082-2099.

Chin, W.W. (2010), "How to write up and report PLS analyses", *Handbook of Partial Least Squares*, Springer, Berlin, Heidelberg, pp. 655-690.

Choi, T.M. (2020), "Supply chain financing using blockchain: impacts on supply chains selling fashionable products", *Annals of Operations Research*, Vol. 1 No. 4, pp. 1-23.

Colicev, A., De Giovanni, P. and Vinzi, V.E. (2016), "An empirical investigation of the antecedents of partnering capability", *International Journal of Production Economics*, Vol. 178, pp. 144-153.

De Giovanni, P. (2020), "Blockchain and smart contracts in supply chain management: a game theoretic model", *International Journal of Production Economics*, Vol. 228 No. 1, p. 107855.

De Giovanni, P. (2021), "Smart contracts and blockchain for supply chain quality management, in dynamic quality models and games", *Digital Supply Chains. How Digital Transformation Impacts Supply Chain Quality Management*, Springer Nature.

De Giovanni, P. (2022), "Blockchain technology applications in businesses and organizations", *IGI-global*. doi: 10.4018/978-1-7998-8014-1.

De Giovanni, P. and Zaccour, G. (2022), "A selective survey of game-theoretic models of closed-loop supply chains", *Annals of Operations Research*, Vol. 17 No. 1, pp. 1-44.

Deloitte (2020), "Omni-channel point of view 5 Product returns: closing the omni-channel loop", available at: https://www2.deloitte.com/content/dam/Deloitte/be/Documents/strategy/POV_Product%20returns_closing%20the%20omnichannel%20loop_vFinal.pdf.

Edbring, E.G., Lehner, M. and Mont, O. (2016), "Exploring consumer attitudes to alternative models of consumption: motivations and barriers", *Journal of Cleaner Production*, Vol. 123 No. 1, pp. 5-15.

Farooque, M., Jain, V., Zhang, A. and Li, Z. (2020), "Fuzzy DEMATEL analysis of barriers to Blockchain-based life cycle assessment in China", *Computers and Industrial Engineering*, Vol. 147, p. 106684.

Frei, R., Jack, L. and Brown, S. (2020), "Product returns: a growing problem for business, society and environment", *International Journal of Operations and Production Management*, Vol. 40 No. 10, pp. 1613-1621.

French, M.L. and LaForge, R.L. (2006), "Closed-loop supply chains in process industries: an empirical study of producer re-use issues", *Journal of Operations Management*, Vol. 24 No. 3, pp. 271-286.

Genc, T.S. and De Giovanni, P. (2017), "Trade-in and save: a two-period closed-loop supply chain game with price and technology dependent returns", *International Journal of Production Economics*, Vol. 183, pp. 514-527.

Govindan, K., Soleimani, H. and Kannan, D. (2015), "Reverse logistics and closed-loop supply chain: a comprehensive review to explore the future", *European Journal of Operational Research*, Vol. 240 No. 3, pp. 603-626.

Guerrero-Lorente, J., Ponce-Cueto, E. and Blanco, E.E. (2017), "A model that integrates direct and reverse flows in omnichannel logistics networks", *Engineering Systems and Networks*, Springer, Cham, pp. 89-97.

Guide, V.D.R., Jr and Van Wassenhove, L.N. (2009), "OR FORUM—the evolution of closed-loop supply chain research", *Operations Research*, Vol. 57 No. 1, pp. 10-18.

Hackius, N. and Petersen, M. (2017), "Blockchain in logistics and supply chain: trick or treat?", in *Digitalization in Supply Chain Management and Logistics: Smart and Digital Solutions for an Industry 4.0 Environment. Proceedings of the Hamburg International Conference of Logistics (HICL)*, Vol. 23, epubli GmbH, Berlin, pp. 3-18.

Hyperledger (2019), "How Walmart brought unprecedented transparency to the food supply chain with hyperledger fabric", Hyperledger.com: Blockchain Technologies for Business, available at: https://www.hyperledger.org/learn/publications/walmart-case-study.

Jin, D., Caliskan-Demirag, O., Chen, F.Y. and Huang, M. (2020), "Omnichannel retailers' return policy strategies in the presence of competition", *International Journal of Production Economics*, Vol. 225, p. 107595.

Kamath, R. (2018), "Food traceability on blockchain: Walmart's pork and mango pilots with IBM", *The Journal of the British Blockchain Association*, Vol. 1 No. 1, p. 3712.

Kamble, S.S., Gunasekaran, A. and Sharma, R. (2020), "Modeling the blockchain enabled traceability in agriculture supply chain", *International Journal of Information Management*, Vol. 52, p. 101967.

Ko, T., Lee, J. and Ryu, D. (2018), "Blockchain technology and manufacturing industry: real-time transparency and cost savings", *Sustainability*, Vol. 10 No. 11, p. 4274.

Koh, L., Dolgui, A. and Sarkis, J. (2020), "Blockchain in transport and logistics–paradigms and transitions", *International Journal of Production Research*, Vol. 58 No. 7, pp. 2054-2062.

Kouhizadeh, M., Zhu, Q. and Sarkis, J. (2020), "Blockchain and the circular economy: potential tensions and critical reflections from practice", *Production Planning and Control*, Vol. 31 Nos 11-12, pp. 950-966.

Kshetri, N. (2018), "1 Blockchain's roles in meeting key supply chain management objectives", *International Journal of Information Management*, Vol. 39, pp. 80-89.

Kuah, A.T. and Wang, P. (2020), "Circular economy and consumer acceptance: an exploratory study in East and Southeast Asia", *Journal of Cleaner Production*, Vol. 247, 119097.

Lakhani, K.R. and Iansiti, M. (2017), "The truth about blockchain", *Harvard Business Review*, Vol. 95 No. 1, pp. 119-127.

Lau, A., Chi, J., Gong, F., Li, L. and Liao, N. (2015), "China's iConsumer 2015: a growing appetite for choice and change", McKinsey & Company, available at: http://www.mckinseychina.com/chinasiconsumer-2015-a-growing-appetite-for-change/.

Levy, M., Weitz, B. and Grewal, D. (2013), *Retailing Management*, McGraw-Hill Education, New York, NY.

Ma, W.M., Zhao, Z. and Ke, H. (2013), "Dual-channel closed-loop supply chain with government consumption-subsidy", *European Journal of Operational Research*, Vol. 226 No. 2, pp. 221-227.

MacCarthy, B.L., Zhang, L. and Muyldermans, L. (2019), "Best performance frontiers for buy-online-pickup-in-store order fulfilment", *International Journal of Production Economics*, Vol. 211, pp. 251-264.

Mandal, P., Basu, P. and Saha, K. (2021), "Forays into omnichannel: an online retailer's strategies for managing product returns", *European Journal of Operational Research*, Vol. 292 No. 2, pp. 633-651.

Manupati, V.K., Schoenherr, T., Ramkumar, M., Wagner, S.M., Pabba, S.K. and Inder Raj Singh, R. (2020), "A blockchain-based approach for a multi-echelon sustainable supply chain", *International Journal of Production Research*, Vol. 58 No. 7, pp. 2222-2241.

Mastos, T.D., Nizamis, A., Terzi, S., Gkortzis, D., Papadopoulos, A., Tsagkalidis, N. and Tzovaras, D. (2021), "Introducing an application of an industry 4.0 solution for circular supply chain management", *Journal of Cleaner Production*, Vol. 300 No. 1, p. 126886.

Naclerio, A.G. (2020), "The combined impact of blockchain and omnichannel on logistics and last mile delivery", available at: SSRN 3668019.

Naclerio, A.G. and De Giovanni, P. (2022), "Blockchain, logistics and omnichannel for last mile and performance", *The International Journal of Logistics Management*, Vol. 33 No. 2, pp. 663-686.

Nageswaran, L., Cho, S.H. and Scheller-Wolf, A. (2020), "Consumer return policies in omnichannel operations", *Management Science*, Vol. 6 No. 12, pp. 5558-5575.

Nandi, S., Sarkis, J., Hervani, A.A. and Helms, M.M. (2021), "Redesigning supply chains using blockchain-enabled circular economy and COVID-19 experiences", *Sustainable Production and Consumption*, Vol. 27, pp. 10-22.

Peng, D.X. and Lai, F. (2012), "Using partial least squares in operations management research: a practical guideline and summary of past research", *Journal of Operations Management*, Vol. 30 No. 6, pp. 467-480.

Pepper, A. and Gore, J. (2015), "Behavioral agency theory: new foundations for theorizing about executive compensation", *Journal of Management*, Vol. 41 No. 4, pp. 1045-1068.

Pezzini, G. (2020), "4 Omnichannel Failures that Could Easily Have Been Avoided with the Right Management System", LS Retail, available at: www.lsretail.com.

Pournader, M., Shi, Y., Seuring, S. and Koh, S.L. (2020), "Blockchain applications in supply chains, transport and logistics: a systematic review of the literature", *International Journal of Production Research*, Vol. 58 No. 7, pp. 2063-2081.

Prandelli, E. and Verona, G. (2020), *Human Digital Enterprise: Creare e co-creare valore in un contesto omni-data*, EGEA spa.

Rehman Khan, S.A., Yu, Z., Sarwat, S., Godil, D.I., Amin, S. and Shujaat, S. (2021), "The role of block chain technology in circular economy practices to improve organisational performance", *International Journal of Logistics Research and Applications*, Vol. 25 Nos 4-5, pp. 1-18.

Rosa, P., Sassanelli, C., Urbinati, A., Chiaroni, D. and Terzi, S. (2020), "Assessing relations between Circular Economy and Industry 4.0: a systematic literature review", *International Journal of Production Research*, Vol. 58 No. 6, pp. 1662-1687.

Ruzza, D., Bernasconi, G. and De Giovanni, P. (2022), "How genuino applies blockchain technology in the collectibles industry", *Blockchain Technology Applications in Businesses and Organizations*, IGI Global, pp. 1-18.

Saberi, S., Kouhizadeh, M., Sarkis, J. and Shen, L. (2019), "Blockchain technology and its relationships to sustainable supply chain management", *International Journal of Production Research*, Vol. 57 No. 7, pp. 2117-2135.

Saghiri, S., Wilding, R., Mena, C. and Bourlakis, M. (2017), "Toward a three-dimensional framework for omnichannel", *Journal of Business Research*, Vol. 77, pp. 53-67.

Savaskan, R.C., Bhattacharya, S. and Van Wassenhove, L.N. (2004), "Closed-loop supply chain models with product remanufacturing", *Management Science*, Vol. 50 No. 2, pp. 239-252.

Shaharudin, M.R., Govindan, K., Zailani, S., Tan, K.C. and Iranmanesh, M. (2017), "Product return management: linking product returns, closed-loop supply chain activities and the effectiveness of the reverse supply chains", *Journal of Cleaner Production*, Vol. 149, pp. 1144-1156.

Son, B.G., Kim, H.J., Daesik, H. and Nachiappan, S. (2021), "The dark side of supply chain digitalisation: supplier-perceived digital capability asymmetry, buyer opportunism and governance", *International Journal of Operations and Production Management*, Vol. 41 No. 7, pp. 1220-1247.

Souza, G.C. (2013), "Closed-loop supply chains: a critical review, and future research", *Decision Sciences*, Vol. 44 No. 1, pp. 7-38.

van Hoek, R. (2019), "Exploring blockchain implementation in the supply chain", *International Journal of Operations and Production Management*, Vol. 39 Nos 6/7/8, pp. 829-859.

Verhoef, P.C., Kannan, P. and Inman, J. (2015), "From multi-channel retailing to omni-channel retailing introduction to the special issue on multi-channel retailing", *Journal of Retailing*, Vol. 91 No. 2, pp. 174-181.

Wamba, S.F., Queiroz, M.M. and Trinchera, L. (2020), “Dynamics between blockchain adoption determinants and supply chain performance: an empirical investigation”, *International Journal of Production Economics*, Vol. 229 No. 1, p. 107791.

Wang, Y., Chen, C.H. and Zghari-Sales, A. (2020), “Designing a blockchain enabled supply chain”, *International Journal of Production Research*, pp. 1-26.

Welfare, A. (2019), *Commercializing Blockchain: Strategic Applications in the Real World*, John Wiley & Sons, Chichester.

Xu, X. and Jackson, J.E. (2019), “Investigating the influential factors of return channel loyalty in omnichannel retailing”, *International Journal of Production Economics*, Vol. 216, pp. 118-132.

Zhao, G., Liu, S., Lopez, C., Lu, H., Elgueta, S., Chen, H. and Boshkoska, B.M. (2019), “Blockchain technology in agri-food value chain management: a synthesis of applications, challenges and future research directions”, *Computers in Industry*, Vol. 109, pp. 83-99.

Zhu, Q. and Kouhizadeh, M. (2019), “Blockchain technology, supply chain information, and strategic product deletion management”, *IEEE Engineering Management Review*, Vol. 47 No. 1, pp. 36-44.

(The Appendix follows overleaf)

Appendix

Construct	Item	Question
Blockchain (B)		*In the last two years, our companies invested in blockchain by*
	B1	Consulting developers
	B2	Modifying the management of contracts and transactions
	B3	Developing tokens
	B4	Developing new platforms
	B5	Initiating new training programs
	B6	Aligning the technology requirement with the regulations
	B7	Integrating blockchain technologies with other digital technologies
		In the last two years, our company invested in the following reverse omnichannel solutions
Reverse Omnichannel (O)	O1	Return to the manufacturer
	O2	Return to the store
	O3	Return to a center
	O4	Return online
	O5	Return to a locker[a]
		In the last two years, our company has invested in the following closed-loop supply chain actions
	CLSC1	Activating recycling operations
Closed-loop Supply Chain (CLSC)	CLSC2	Investing in refurbishing and remanufacturing of returned items
	CLSC3	Improving the Information System to track returns
	CLSC4	Using specialized Third Party Logistics to acquire returns
	CLSC5	Offering replacement goods to consumers
	CLSC6	Offering cheap return options[a]
		In the last two years, our company has performed in terms of
	BP1	Market share
Business Performance (BP)	BP2	Profits
	BP3	ROI
	BP4	Cost savings
	BP5	Environmental impact
	BP6	Cost for energy

Note(s): [a]Excluded from the analysis

Table A1.
Questionnaire

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