Blockchain entrepreneurship roles for circular supply chain transition

KAYIKCI, Yasanur <http://orcid.org/0000-0003-2406-3164>, GOZAN-CHASE, Nazlican and REJEB, Abderahman

Received: 8 November 2022 | Revised: 24 May 2023 | Accepted: 4 June 2023

DOI: 10.1002/bse.3489

RESEARCH ARTICLE

Business Strategy and the Environment WILEY

Blockchain entrepreneurship roles for circular supply chain transition

Yasanur Kayikci[1,2] | **Nazlican Gozacan-Chase**[3] | **Abderahman Rejeb**[4]

[1]Sheffield Business School, Sheffield Hallam University, Sheffield, UK

[2]Science Policy Research Unit, University of Sussex Business School, Brighton, UK

[3]International Logistics Management Department, Yasar University, Izmir, Turkey

[4]Department of Management and Law, Faculty of Economics, University of Rome Tor Vergata, Rome, Italy

Correspondence
Yasanur Kayikci, Sheffield Business School, Sheffield Hallam University, Stoddart Building, Room 7207, Howard St, Sheffield S1 1WB, UK.
Email: yasanur.kayikci@gmail.com; y.kayikci@shu.ac.uk and yk327@sussex.ac.uk

Funding information
Scientific and Technological Research Council of Turkey, Grant/Award Number: 1929B021801076

Abstract

The transition to a circular supply chain (CSC) is a prerequisite to establish sustainability in the supply chain. Blockchain-based CSC enables stakeholders to effectively manage their decision-making processes, increase revenue, reduce time and costs and ensure information synchronisation. Blockchain start-ups play an essential role in facilitating the transition from a linear to a circular economy while supporting the development of CSCs. This research aims to explore the role of blockchain entrepreneurship in the transition to CSC by evaluating circular blockchain start-ups. This research contributes to the literature by providing verified roles of blockchain entrepreneurship in the transition to CSC by evaluating the literature and blockchain start-ups. Another contribution is that the causal relationships between these roles are analysed. In this study, an integrated three-step methodology including Systematic Literature Review (SLR), Qualitative Comparative Analysis (QCA), and Fuzzy Decision-Making Trial and Evaluation Laboratory (Fuzzy-DEMATEL) methods on the base of the theory of change is proposed. An SLR is performed to determine the roles of blockchain entrepreneurship. Then, a QCA is conducted after identifying the roles for verification by evaluations of use cases of blockchain start-ups. Finally, the causal relationships between these roles are interpreted by using Fuzzy-DEMATEL. Findings indicate that blockchain entrepreneurship has 12 fundamental roles in facilitating the transition from a linear to a circular economy while supporting the development of CSCs.

KEYWORDS

blockchain entrepreneurship, circular supply chain, Systematic Literature Review, Qualitative Comparative Analysis, Fuzzy-DEMATEL, theory of change

1 | INTRODUCTION

Circular economy (CE) concept receives considerable attention both in academia and industry (Choudhary et al., 2022). Over the last decade, the CE notion has been established to assist with the issues of resource depletion and environmental degradation (Geissdoerfer et al., 2017; Rejeb, Suhaiza, et al., 2022; Stahel, 2016). Each stakeholder has a unique viewpoint and understanding of what constitutes CE; hence, the term is open to several interpretations. For instance, Kirchherr et al. (2017) propose a comprehensive conceptualisation of the CE by describing it as a sustainable model in which resources used in manufacturing, distribution, and consumption are conserved and reused as much as possible, with a focus on reclaiming materials via recycling. In order to attain entrepreneurial sustainability, Zamfir et al. (2017) state that the CE practices at the business level might involve waste minimisation while maintaining the value of materials and outputs in the chain. The CE functions at the micro- (products, firms, customers), meso- (industrial symbiosis), and macro-levels (government, region, country, and beyond) to achieve economic growth, environmental quality, and sustainable development (Grafström & Aasma, 2021; Korhonen et al., 2018; Morseletto, 2020).

The incorporation of sustainability-related benefits with CE practices such as recycling, reuse and a zero-waste ideal has led to the wide integration of the CE in the supply chain, also called circular supply chain (CSC) (Montag, 2022). An environmentally sustainable SC strategy is required encompassing eco-friendly and energy-efficient operations, technology, and commodities (Gotschol et al., 2014; Kazancoglu et al., 2020) as CSC has become a strategic variable for organisations, going beyond environmental aspects (González-Sánchez et al., 2020). CSC has the benefit of rescuing discarded materials from landfills by recovering their potential and reusing them in the development of by-products (Genovese et al., 2017; Kazancoglu et al., 2020). CSC facilitates the transition of a linear supply chain towards a circular structure (Mangla et al., 2018). Introducing innovative business strategies based on CE principles, CSC presents a great opportunity for linear supply chains (Asante et al., 2022) to improve the allocation of resources to encourage environmental manufacturing as well as consumption (Fehrer & Wieland, 2021). CSC focuses on material processes in supply chains through accelerating, dematerialising, eliminating, delaying and shrinking material cycles (Geissdoerfer et al., 2018).

Innovative solutions to sustainability issues and better Circular Supply Chain Management (CSCM) via the use of new technologies are acknowledged (Rejeb, Suhaiza, et al., 2022). The internet of things, artificial intelligence, blockchain technology, additive manufacturing, robotics, and so on, are a few examples of new technologies that support the development of circular business models (Laskurain-Iturbe et al., 2021; Tiwari et al., 2021). A sustained competitive advantage can be achieved with the help of these technologies, which include areas such as business process reengineering, digital information management and the execution of optimisation strategies (Chakrabarty & Nandi, 2021; Kazancoglu et al., 2021).

The expansion of entrepreneurship is closely related to strengthening the national, societal, and individual economies (Schiavone et al., 2021). Blockchain entrepreneurship can maintain effective, constructed encryption to assist with safely storing and moving data. Accordingly, blockchain entrepreneurship significantly influences CSC operations, assets, raw materials, products, and processes because of its trust, transparency, traceability (Centobelli et al., 2022), reduced transaction cost, enhanced performance, human rights protection (Upadhyay et al., 2021), security, reliability, real-time data and smart contracts (Kayikci, Durak Usar, & Aylak, 2021). To assist this effort, blockchain is appropriate for identifying, and tracking products and items throughout the supply chain (Mangla et al., 2022), and ensuring that they may be reused, remanufactured, and recycled (Böhmecke-Schwafert et al., 2022). For trustworthy cooperation, blockchain-based CSC may demand a more restricted, private, and permissioned blockchain with several and controlled participants (Centobelli et al., 2022). Additionally, blockchain technology provides participants with better control over resource utilisation (Tseng et al., 2018); measures gas emissions and the green condition of products (Wang et al., 2020); manages reverse supply chains (Dutta et al., 2020); and minimises waste by delivering highly accessible products (Kayikci et al., 2022).

While prior research works contributed to an increased understanding of blockchain in the CSC context, there is a lack of studies looking at how technology as an entrepreneurship platform can facilitate CSCM in certain sectors. Additionally, there is no research on the impact of blockchain-based start-ups on managerial decision-making to further the development and growth of CSC. The motivation of the study is to bridge this knowledge gap by proposing an integrated three-step methodology on the base of the theory of change. A Systematic Literature Review (SLR) is conducted to examine the fundamental roles of blockchain entrepreneurship in the CSC. To sharpen our theoretical focus, a qualitative case analysis technique: Qualitative Comparative Analysis (QCA) is performed to evaluate these roles from real-world use cases. The identified roles are validated in six start-ups. Moreover, a multi-criteria technique, Fuzzy-DEMATEL, is applied to interpret the causal relationships between these factors in the CSC transition. The roles are examined based on expert opinion. Research questions are generated by examining and critiquing the literature already published. This study mainly examines the following two research questions to fulfil the research gap:

RQ1. What are the fundamental roles of blockchain entrepreneurship in the circular supply chain transition?

RQ2. What are the causal interrelationships between these roles of blockchain entrepreneurship in the circular supply chain transition?

The paper is structured as follows. After the introduction section, the paper presents the research background and theory in Section 2. The research design of the paper, which proposes a three-stage integrated methodology, is given in Section 3. Then, the results of the study are presented in Section 4. Section 5 gives a discussion of this study. Finally, Section 6 concludes the study by drawing suggestions based on the findings and discussing the limitations and future research directions.

2 | RESEARCH BACKGROUND AND THEORY

2.1 | CSC

CSCM represents a new area of sustainability that has been introduced to the supply chain (Du et al., 2010; Nasir et al., 2017). Sustainable practices, including reverse logistics (Fleischmann et al., 1997; Rogers & Tibben-Lembke, 2011; Rubio et al., 2008), green supply chain (Beamon, 1999; Min & Kim, 2012; Srivastava, 2007), integration of CSC collaboration and circularity (Gebhardt et al., 2021), closed-loop supply chain systems (De Giovanni, 2022; Kumar & Rahman, 2014; Li, 2013) and industrial symbiosis (de Abreu & Ceglia, 2018; Domenech et al., 2019; Tseng et al., 2018); responsibility and liability of manufacturers (Deutz et al., 2017; Du et al., 2020; Xavier et al., 2021); and development of eco-industrial park (Belaud et al., 2019; Martín Gómez et al., 2018) are considered. Multiple definitions of CSCM emerge when the importance of CE is considered in the supply chain. Conceptually, CSCM is a harmonised forward and supply chain via the inclusion of value-generating elements from goods, by-products and usable waste over a longer life cycle that enhances economic, environmental and social sustainability (Batista et al., 2019). CSCM seeks to optimise the use of natural resources by restoring, regenerating and better capturing the values of those resources (Mangla et al., 2018). MacArthur (2015) further describes the CE in terms of the supply chain as an industrial system that aims to restore or regenerate its resources. Improvements in value propositions, resource consumption, end-of-life approaches, waste generation rates, social benefits and sustainability are just some of the many outcomes of incorporating CE into supply chains (Farooque et al., 2019). The advantages of CSCM motivate scholars and practitioners to re-evaluate their supply chain and consider the adoption of CE. Since recycling or reusing all undesirable materials in the same supply chain is usually impractical, a closed-loop system creates considerable waste. As a result, by collaborating with other firms in the same industry or in other industries, a CSC enables to recover more value from waste (Romero-Hernández & Romero, 2018; Tomić & Schneider, 2018). CSC is meant to systematically replenish and renew resources in the natural and industrial environment, thereby generating minimum waste. In this context, CSCM should be explored thoroughly in order to discover innovative circular business models and novel approaches utilising sophisticated quantitative modelling tools including integrated multi-criteria decision-making methodologies (Lahane et al., 2020).

2.2 | Blockchain technology

Satoshi Nakamoto (pseudonym) is widely credited as the inventor of blockchain technology after publishing a paper on the topic in 2008 (Nakamoto, 2008). Satoshi suggested in the paper an open distributed ledger for the Bitcoin cryptocurrency. Numerous industries outside the cryptocurrency realm are paying close attention to blockchain technology (Rejeb et al., 2019). Blockchain has been considered both a revolutionary and game-changing technology. As a distributed ledger technology, blockchain is distinguished by its accessibility, transactional immutability, and resistance to tampering and manipulation (Treiblmaier, 2018). Three distinct generations of blockchain have arisen since the introduction of the technology, each with its own set of use cases and technical characteristics (Kayıkcı & Subramanian, 2022; Cheng et al., 2021; Xu et al., 2019). Blockchain's original version was designed with cryptocurrencies in mind, namely, the necessity to enable the decentralised, peer-to-peer trading of digital money between users without the intervention of a trusted third party such as banks (Nakamoto, 2008). In most cases, anybody may join the Bitcoin network and transact with other users since the blockchain is open to the public. To keep track of its expanding list of blocks, each of which is a single transaction record, blockchain uses encryption (Gunasekara et al., 2022; Meng et al., 2018; Xu et al., 2021). Blockchain transactions become permanent after they have been updated and authenticated by all necessary parties. This makes the technology a highly trustworthy and secure ledger that can be relied upon to record transactions in an immutable and accurate manner (Treiblmaier, 2018). Furthermore, blockchain's peer-to-peer structure ensures that all network users can see and verify any ledgers' most recent changes. Another definition for blockchain is an ever-growing, decentralised, yet shared ledger that is cryptographically secured by means of digital footprints (Kayikci et al., 2022).

Cryptocurrency mining is used to insert new blocks in the blockchain, and it works by having miners solve a mathematical problem using complex calculations until a certain value is reached. In the blockchain, miners race to be the first to add new blocks to the distributed ledger by solving a complex computational task. Those involved are then rewarded for their efforts with cryptocurrency. Every single block in the blockchain should have a proof-of-work, which is checked and certified by the rest of the network. This ensures the whole chain's security and resistance to tampering (Kayıkcı & Subramanian, 2022; Kayikci et al., 2022). Blockchain is built to limit the total supply of cryptocurrency. Therefore, the system relies on simultaneous cooperation and rivalry among network users (Chiu & Koeppl, 2019; Li et al., 2019).

Smart contracts are part of the second generation of blockchain technology (Yu et al., 2019). They allow the parties to predetermine the terms of the agreement and the conditions under which it will be executed. Eliminating the need for a neutral third party, which is crucial to the current escrow system, this automated system proves that contracts can be formed using just computer codes. Since the introduction of smart contracts has the potential to minimise transaction costs, risks and expedite payment processes (Chaudhuri et al., 2021), the second generation of blockchain fundamentally disrupts the current understanding of supply chains (Swan, 2015). This development paves the way for introducing the third generation of blockchain when the social aspects of the technology are stressed. Manufacturing, tourism, healthcare, transportation, logistics, and supply chain management all benefit from the innovations made possible by blockchain (Rejeb, Rejeb, et al., 2021; Treiblmaier, 2018). The core features of blockchain, such as encryption, distributed storage, robust security, peer-to-peer transactions, and the prospect of efficient and safe automation, are what make this generation of technology appealing to many different sectors, including CSCs (Centobelli et al., 2022; Huang et al., 2022; Paul et al., 2022; Wang et al., 2020).

Based on the explained concept, similar studies are reviewed. Blockchain for business strategies as a management tool for CSC can enhance the environment, sustainability in supply chains by generating awareness among a diverse multidisciplinary area. Research into blockchain's potential applications in CSC has seen a rise in attention from academia. For example, in order to develop a conceptual framework to investigate the connection between blockchain, CE, and total productive maintenance, Samadhiya et al. (2023) used structural equation modelling. The natural resource-based view theory was utilised as the foundation for the research. By implementing AHP-DEMATEL, Chaouni Benabdellah et al. (2023) researched the interdependencies and causal linkages between the main barriers to the adoption of blockchain in viable circular digital supply chains. Moreover, Huang et al. (2022) intend to establish a framework that explains the major stages of blockchain-based CSCM and assesses critical success factors of the technology in CSCM. By applying the Analytical Hierarchy Process and DEMATEL, the findings demonstrate the criticality of technical capability, technological maturity, and technological feasibility in CSCM. Finally, Kayikci et al. (2022) examine the critical success factors associated with deploying blockchain-enabled CSCs and identify network collaboration as the best factor and the shared CE toolbox as the worst factor. To describe the complexity of the network infrastructure for the B2B tea sector, Paul et al. (2022) focused on an RFID-integrated blockchain-driven CSC model. Moreover, by concentrating on the function that blockchain interacts with in circular blockchain platforms, Centobelli et al. (2022) propose the integrated Triple Retry framework for developing circular blockchain systems to link traceability, trust, and transparency with the three CSC reverse operations, including recycling, redistribution, and remanufacturing. The findings point to the value of blockchain as a technological tool for tightening the regulation of waste stream and product return management processes. Wang et al. (2020) initiate the development of a system architecture for blockchain-enabled CSCM in the fast-fashion sector. Esmaeilian et al. (2020) provide an overview of Industry 4.0 and blockchain technology for improving CSCM implementation. As the literature is reviewed, to the best of our knowledge, there is no study providing verified roles of blockchain entrepreneurship in the transition to CSC by evaluating the literature and blockchain start-ups with a three-step methodology including SLR, QCA and Fuzzy-DEMATEL methods on the base of the Theory of Change. The study's most important takeaways are its status as a ground-breaking analysis of blockchain entrepreneurship roles in CSC. The findings are investigated and used to advance the state of the art in blockchain and entrepreneurship towards the goal of developing CSC at the level of the practitioner. Therefore, this research contributes to the extant literature in numerous important ways: Firstly, the impact of blockchain entrepreneurship on CSC is investigated. Secondly, fundamental roles of blockchain entrepreneurship are identified from the literature and empirically validated by experts. Thirdly, fundamental roles are recognised, and their inter-relationships are assessed. Lastly, recommendations and implications from a practitioner's standpoint are highlighted.

2.3 | Theory of change

The concept of the theory of change first appeared in the late 1980s and early 1990s (Connell & Kubisch, 1998), in improvising evaluation theory and practices associated with the field of community actions (Khanna et al., 2022). The theory of change is an essential roadmap with a comprehensive description and illustration of how and why the desired change is expected to happen in a particular context (Annie, 2004). It is focused on mapping and learning what a programme or change initiative does and how these lead to desired goals being achieved (Brest, 2010). It does this by first identifying the desired long-term goals and then working back from these to identify all the conditions that must be in place and how these relate to one another causally for the goals to occur (Mackenzie & Blamey, 2005). Theory of change is a systematic and collective study approach to the relevance of the CE and describes its linkages between inputs, activities, outputs, outcomes, and impacts (Khanna et al., 2022) on short-term and long-term goals (Weiss, 1995). These are all mapped (Annie, 2004; Khanna et al., 2022). There are two approaches under the theory of change which are the Multi-Level Perspective (MLP) approach and the disruptive innovation approach. In this matter, two theoretical approaches are considered, which are the MLP approach and the disruptive innovation approach (Mouffak, 2021).

2.3.1 | MLP approach

The MLP approach helps to understand how innovations in a society succeed and, therefore, how the different socio-technical systems gradually change (Mouffak, 2021). The MLP posits that transitions come about through interaction processes within and among three analytical levels: niches, socio-technical regimes, and a socio-technical landscape (El Bilali, 2019). According to the MLP method, the first layer of the socio-technical system is the general landscape, also referred to as the macro-level, which refers to the external surroundings that impact all participants (Geels, 2019). It is made up of patterns and modifications that normally happen slowly, across decades. The patchwork of regimes is the second layer of the socio-technical system, often defined as the meso-level (Genus & Coles, 2008). These are predicated on the sustained performance of all the operations and mechanisms that comprise a socio-technical system (Geels, 2019). The third layer of the socio-technical system, also referred to as the micro-level, is niches. It comprises alternative ideas or technology, which are often created in controlled creative areas. The niche players want to gradually incorporate their innovations into the present regime (Genus & Coles, 2008). However, niches are vital for society as pillars for modernisation and system updates. As a result, if a niche succeeds in expanding its market, increasing demand, and receiving greater assistance, it not only modifies the regime but also impacts the landscape (Mouffak, 2021).

2.3.2 | Disruptive innovation approach

According to Christensen Institute (2016), disruptive innovation is the process by which a product or service initially posits itself in basic forms at the bottom of a sector, generally through being lower in price and greater abundance, and afterward steadily rises, eventually displacing incumbent rivals. According to the approach, once the concept of disruption is extended to industry, everything that emerges and succeeds in such a marketplace may be considered disruptive (Larson, 2016). Furthermore, disruption can take two forms: low-end disruption that emphasises the high-sales customers and innovative disruption that emphasises the underserved buyers (Larson, 2016). Blockchain is the most recent disruptive innovation that has piqued the interest of researchers (Frizzo-Barker et al., 2019). Blockchain technology has been predicted by the sector and academic world as a disruptive technology that can perform a fundamental role (Rane & Narvel, 2021). Swan (2015) categorises blockchain into three forms: *Blockchain 1.0* for currency; *Blockchain 2.0* for contracts; and *Blockchain 3.0* for non-financial purposes (Frizzo-Barker et al., 2019). The exploration of these roles for blockchain entrepreneurship for the CSC transition is covered in the next sections.

3 | RESEARCH DESIGN

An integrated three-step methodology including SLR, QCA and Fuzzy-DEMATEL is proposed to explore and examine the role of blockchain entrepreneurship in the transition to CSC. The three-step methodology is performed on the base of the theory of change. The fundamental roles of blockchain entrepreneurship in the CSC transition are defined by conducting an SLR that is explained in depth in Section 3.1. In the meantime, blockchain use cases are selected. Also, the selected use cases are analysed by employing QCA explained in Section 3.2 by verifying the determined roles to answer RQ1, and lastly, in Section 3.3, the causal relationships among the roles of blockchain entrepreneurship in the shift to a CSC are interpreted by Fuzzy-DEMATEL to respond RQ2.

An overview of the research paper is demonstrated briefly in Figure 1. The following sections explain the process of the methodologies and the results of the research that are demonstrated above in detail.

3.1 | SLR

A rigorous review of the domain literature through an SLR was implemented to obtain the blockchain entrepreneurship roles in the CSC. An SLR was conducted to answer formulated research questions that use systematic and reproducible methods to identify, select and critically appraise all relevant research (Thomé et al., 2016). Firstly, a systematic search using the following search string based on the search keywords in multiple databases seen in Table 1 was established for the search of the state-of-the-art review.

The most relevant papers for evaluation in this research were determined after a detailed assessment and review of the existing literature. Furthermore, pertinent documents were discovered by a full examination of the Scopus and Web of Science databases. The primary purpose was to include the search keywords or strings in the sections including titles, abstracts, and keywords. In the databases, the first search results yielded 516 and 483 documents, correspondingly. The retrieved publications were analysed under the criteria for inclusion, confirming that they were English-speaking as well as peer-reviewed to gather high-quality and validated information (Alnajem et al., 2020). Publications were further scrutinised to identify duplication, and the resulting 83 articles were evaluated separately considering relevance. A number of 72 papers completed the preliminary assessment and were comprehensively reviewed. Papers that did not correspond with the objective of the research were eliminated, and 47 papers were accepted following the diagonal examination. Following a comprehensive document review, 50 journal articles were eligible for analysis and maintained for the ultimate assessment. To avoid biases in the identification of blockchain roles, two reviewers from academia have participated in the deep analysis of publications as well as the coding phase (Thomé et al., 2016) to enhance the reliability and validity of the assessment. Twelve blockchain roles were discovered and collected following a comprehensive SLR. As an outcome of this SLR, the 12 blockchain roles discovered are detailed in depth in Section 4.2.

3.2 | QCA

QCA is a systematic case-based method for analysing data to explain what roles lead to specific outcomes. In this research, the focus is on blockchain roles that lead to a circular process, so, it is necessary to use a methodology with which it is possible to 'establish causal relationships through systematic comparisons' (Intrac, 2017). The process of conducting a QCA follows formal steps explained below that are replicable:

Step 1 - *Develop a theory*: The theory of change is explained including the MLP Approach and Disruptive Innovation Approach in Section 2.2.

Step 2 - *Identify blockchain start-ups to analyse*: In this research, blockchain start-ups are analysed for comparison to verify the blockchain roles. These blockchain start-ups are mentioned in Section 4.1. in detail as a part of the QCA process.

Step 3 - *Define the set of blockchain roles*: In this step of the QCA process, it is important to define a set of blockchain roles in which their presence or absence can result in a particular start-up. An SLR is employed to provide an in-depth and critical summary of existing research to define the roles. The SLR process and blockchain roles identified are explained in Section 4.2.

Step 4 - *Calibration process*: In simplified terms, undertaking QCA involves (i) devising rules for operationalising different forms of data into values of 0 or 1 (crisp-set QCA); (ii) creating a 'truth table' revealing how different combinations of antecedent condition sets (analogous to variables) overlap with outcome sets; and (iii) using Boolean algebra to reduce multiple configurations of conditions that appear from truth tables

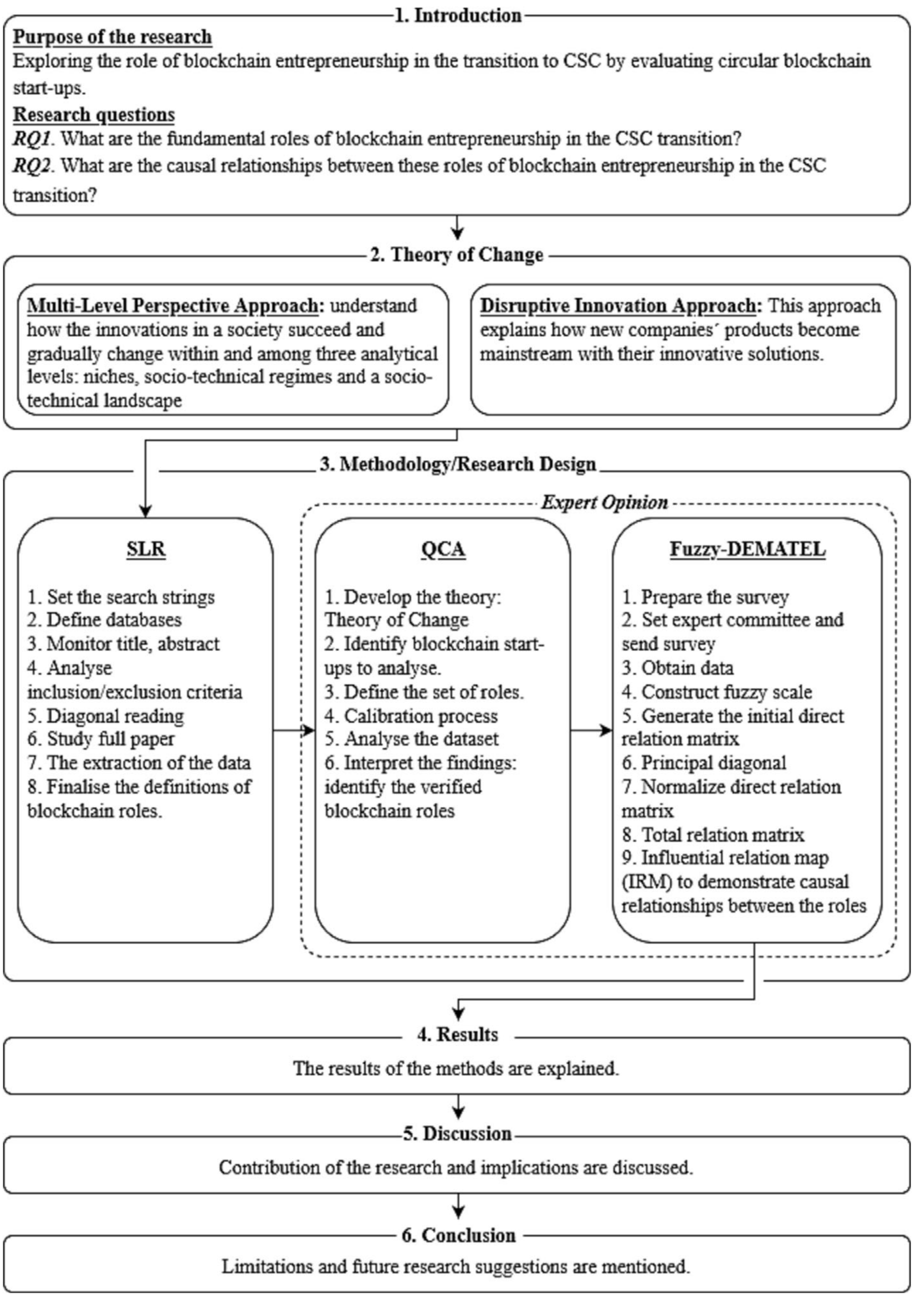

FIGURE 1 Overview of the research paper.

to trigger outcomes down to their instrumental parts, to form more parsimonious solutions.

Step 5 - *Analyse the dataset*: After all cases are scored for each condition, the process of identifying which conditions are necessary, which are sufficient, and which must be absent for an outcome to emerge is performed. When different conditions lead to the same outcome, it is said that this particular outcome has multiple sufficient conditions. When using the cs-QCA, this process is also known as Boolean minimisation, and it consists of detecting irrelevant conditions to make simpler the reason an outcome emerges. An irrelevant condition is one that has no effect on an outcome whether it appears or not. This step is usually done with software.

Step 6 - *Interpret the findings*: The ultimate step involves arguing whether the results obtained from performing the previous steps make sense. For this, the findings will be used to explain each individual case and argue whether these make sense for all cases. Additionally, it is necessary to judge whether these findings concord with the theory of change established in Step 1. In case the findings do not make sense, the whole process should be re-analysed to identify what is the cause of these results. This can range from analysing whether the study cases are consistent with each other, whether the established conditions make sense, whether the scoring process is done correctly and whether there was an error during Step 5. Hence, this makes the QCA an iterative process (Intrac, 2017).

TABLE 1 Search string with search keywords

Search keywords	Search string
'blockchain technology', 'circular supply chain', 'blockchain entrepreneurship'	TITLE-ABS-KEY {('blockchain' OR 'block-chain' OR 'block chain') AND ('supply chain' OR 'circular supply chain') AND ('circular economy' OR 'circularity' OR 'closed-loop' OR 'reverse logistics' OR 'circular business model*' OR 'industrial symbiosis' OR 'cradle') AND ('entrepreneur*' OR 'start-up' OR 'startup' OR 'new venture' OR 'new enterprise' OR 'new business' OR 'new compan*' OR 'small business*' OR 'small venture' OR 'small compan*' OR 'small and medium enterpris*')}. Limit to: Doctype (article and review)

3.3 | Fuzzy-DEMATEL

This section explains the method to analyse the causal relationship between the blockchain roles that are identified and verified in the prior steps. In order to conduct this analysis, Fuzzy-DEMATEL is selected as the methodology. Decision-makers are likely to give evaluations based on their past expertise, knowledge and observations; correspondingly, they often express their estimates in equivocal linguistic terms. The fuzzy set theory assists researchers in dealing with the vagueness of human thoughts and language in decision-making (Lin & Wu, 2008) because the outcome of the decision-making process is substantially affected by the subjective judgement that is vague and indecisive (Wu & Lee, 2007).

3.3.1 | DEMATEL

DEMATEL is a detailed approach for gathering group understanding in an attempt to develop and analyse a structural model and depict sub-systems including complex causal relationships using a causal diagram (Wu & Lee, 2007). The DEMATEL approach can improve comprehension of a given situation, or a group of interrelated problems, and encourage the discovery of relevant alternatives through a hierarchy. The following is an updated version of the DEMATEL terminology and stages acquired from Fontela and Gabus (1976) and Wu and Lee (2007),

Step 1 *Creating the initial direct relation matrix Z*: A pairwise comparison scale is required to compute the first direct relation matrix. For this reason, the interaction between any two factors must be examined by asking participants to identify the direct relationship utilising an integer scale divided into four categories as follows: 'No influence (0)', 'Low influence (1)', 'Medium influence (2)', 'High influence (3)' and 'Very high influence (4)'.

Step 2 *The initial direct relation matrix Z*: It is a [*nxn*] matrix generated using pairwise comparisons as seen in Equation 2. Participants evaluated the criteria in terms of effects and directions, with z_{ij} representing the decision-maker's opinions and defined as the extent to which criterion D_i impacts criterion D_j as seen in Equation 1. The received data were entered into a matrix with all primary diagonal members equal to zero.

$$z_{ij} = \frac{1}{l}\sum\nolimits_{k=1}^{l} z_{ij}^{k},\ \ i,j = 1,2,\ldots,n. \tag{1}$$

$$Z = \begin{matrix} & D_1 & D_2 & \ldots & D_n \\ D_1 & 0 & z_{12} & \ldots & z_{1n} \\ D_2 & z_{21} & 0 & \ldots & z_{2n} \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ D_n & z_{n1} & z_{n2} & \ldots & 0 \end{matrix}. \tag{2}$$

Step 3 *Normalised direct-relation matrix X*: Equation 3 is used to calculate and establish the normalised direct-relation matrix X:

$$X = \frac{Z}{s},\quad s = \left(\sum\nolimits_{j=1}^{n} z_{ij}, \sum\nolimits_{i=1}^{n} z_{ij}\right). \tag{3}$$

All the components in the matrix X adhere to 0 ≤ xij < 1, 0 ≤ Σn $j = 1$ xij ≤ 1, and at least one i such that Σn $j = 1$ zij ≤ s.

Step 4 Calculation of the total relation matrix *T*: which can be defined as seen in Equation 4:

$$T = X + X^2 + X^3 + \ldots + X^h = X(1-X)^{-1},\quad \text{when}\, h \to \infty, \tag{4}$$

where 'I' is represented by an identity matrix.

Step 5 *Generating the influential relation map (IRM)*: The sums of the rows and columns are calculated independently in this phase and labelled as *D* and *R* within the total relation matrix as seen in Equation 5:

$$R = [r_i]_{n\times 1} = \left[\sum\nolimits_{j=1}^{n} t_{ij}\right]_{n\times 1},\quad C = [c_j]_{1\times n} = \left[\sum\nolimits_{i=1}^{n} t_{ij}\right]_{1\times n}^{T}, \tag{5}$$

where D and R represent the total of rows and columns, correspondingly.

Step 6 *Establishment of the causal diagram*: By mapping the datasets and adding or deleting the C from R (R+C, R-C), a causal diagram may be created. The formula (R + C) defines the horizontal axis and is referred to as 'Relation'. On the other hand, the formula (R − C) indicates the vertical axis and is referred to as 'Influence'.

3.3.2. Fuzzy logic

Decision-makers are prone to make assessments depending on their prior expertise, knowledge and judgements; as a result, they frequently convey their estimations in ambiguous linguistic terms. As a result, these linguistic variables must be translated into fuzzy numbers, and triangular fuzzy numbers are used for this purpose as in Table 2. A triangular fuzzy number is represented by three triangles (l,m,r) and a membership. The idea of fuzzy relations, the concept of extension and possibility distributions are all central to fuzzy set theory (Yager & Filev, 1994).

The membership function is described as seen in Equation 6:

$$\mu x(y) = \begin{cases} 0, & x < l, \\ (y-a)/(b-a), & l \le x \le m \\ (c-y)/(c-b), & m \le x \le r, \\ 0 & x > r, \end{cases} \tag{6}$$

Converting Fuzzy Data into Crisp Scores (CFCS) is a defuzzification approach that relies on the ability to calculate the maximum and lowest of a fuzzy integer range. The overall score may then be computed as a weighted average using the membership function (Opricovic & Tzeng, 2003). Let $A_{ij} = \left(l_{ij}^n, m_{ij}^n, r_{ij}^n\right)$ mean the degree to which criterion$i$ influences criterion j according to fuzzy questionnaires $n\,(n = 1,2,3 \ldots p)$. The CFCS technique consists of five steps, which are as follows:

1. Normalisation:

$$\begin{aligned} xl_{ij}^k &= \left(l_{ij}^k - minl_{ij}^k\right)/\Delta_{min}^{max,} \\ xm_{ij}^k &= \left(m_{ij}^k - minl_{ij}^k\right)/\Delta_{min}^{max,} \\ xr_{ij}^k &= \left(r_{ij}^k - minl_{ij}^k\right)/\Delta_{min}^{max,} \\ &\text{where } \Delta_{min}^{max = maxr_{ij}^k - minl_{ij}^k}. \end{aligned} \tag{7}$$

2. Determine the normalised values for the left (*ls*) and right (*rs*):

$$\begin{aligned} xls_{ij}^k &= xm_{ij}^k / \left(1 + xm_{ij}^k - xl_{ij}^k\right), \\ xrs_{ij}^k &= xr_{ij}^k / \left(1 + xr_{ij}^k - xm_{ij}^k\right). \end{aligned} \tag{8}$$

3. Calculate the overall normalised crisp value:

$$x_{ij}^k = \left[xls_{ij}^k\left(1 - xls_{ij}^k\right) + xrs_{ij}^k xrs_{ij}^k\right] / \left[1 - xls_{ij}^k + xrs_{ij}^k\right]. \tag{9}$$

4. Compute crisp values:

$$z_{ij}^k = minl_{ij}^k + x_{ij}^k \Delta_{min}^{max}. \tag{10}$$

5. Integrate crisp values:

$$z_{ij}^k = \frac{1}{p}\left(z_{ij}^1 + z_{ij}^2 + \cdots + z_{ij}^p\right). \tag{11}$$

This section explained the process of the methodologies to identify and analyse the blockchain roles for circular blockchain start-ups. Following section presents the results of the blockchain roles and analysis step by step as provided in Figure 1.

TABLE 2 The relationship between linguistic terminology and linguistic values

Normal values	Linguistic terms	Linguistic values
4	Very high influence (VH)	(0.75, 1.0, 1.0)
3	High influence (H)	(0.5, 0.75, 1.0)
2	Low influence (L)	(0.25, 0.5, 0.75)
1	Very low influence (VL)	(0, 0.25, 0.5)
0	No influence (No)	(0, 0, 0.25)

4 | RESULTS

To answer the research questions defined at the beginning of the paper, SLR is performed to identify the roles of blockchain as explained in Section 3.1. Twelve blockchain roles were discovered and collected following a comprehensive SLR. As the second step, QCA is conducted after identifying the roles for verification by evaluations use cases of start-ups. Finally, the causal relationships between the roles are analysed by using Fuzzy-DEMATEL. The detail of the procedure is explained in this section.

4.1 | Role definition

This section enumerates the main roles of blockchain entrepreneurship in the shift to a CSC as the results of SLR with a perspective of theory of change. To provide the answer for RQ1, the total numbers of roles belonging to blockchain entrepreneurship for the shift to a CSC are 12, which are as follows: Supporting CE practices (eco-design, recycling, green logistics) (R1), Supporting the development of industrial symbiosis (R2), Supporting waste management (R3), Strengthening collaboration and coordination (R4), Providing end-to-end traceability (R5), Alleviating financial problems (R6), Supporting product deletion strategies (R7), Strengthening the competitive advantage of CE business models (R8), Information and knowledge sharing (R9), Supporting clean energy products (R10), Supporting trading activities (R11) and Improving process efficiency (R12). The roles are explained as follows:

- **Supporting CE practices (eco-design, recycling, green logistics) (R1)**: The adoption of a more sustainable business model by start-ups and small and medium enterprises (SMEs) can improve the integration of CE activities, and blockchain technology can play a part in this transition (Pizzi et al., 2021). Increasing resource efficiency and closing or slowing the material loop thanks to blockchain are all ways in which the technology can support CE practices (Huang et al., 2022; Kouhizadeh et al., 2019). As the development of sustainable product designs requires environmental knowledge and skills (Kouhizadeh et al., 2019), there is a potential for blockchain to manage organisational capabilities and monitor business performance, particularly for information and products flowing across the CSC (Centobelli et al., 2022). Energy efficiency can be achieved by the use of blockchain in the continuous and precise monitoring of product manufacturing and consumption data. Through its capacity to track products and materials back to their sources, blockchain can provide data to assess product energy consumption, discover any energy issues and allow for more informed and efficient product design decisions (Kouhizadeh et al., 2019). Furthermore, blockchain provides better recycling performance in the CSC context (Chidepatil et al., 2021; Khadke et al., 2021). Tokenised digital savings enabled by blockchain can be developed to trace and track recycled materials and secure payments for recyclers without the need to invest in a separate security system (Chaudhuri et al., 2022). Finally, organisations can leverage blockchain to make the best possible choices and implement the best possible solution in the pursuit of green logistics and the achievement of sustainable operations (Khan, Godil, et al., 2021). SMEs may benefit from the technology since it encourages the implementation of green information systems and the improvement of economic, operational and environmental performance (Khan, Godil, et al., 2021). Green logistics initiatives based on blockchain also help bolster a company's reputation, save costs, conserve resources and increase profit margins (Tan et al., 2020).
- **Supporting the development of industrial symbiosis (R2)**: Blockchain enables the effective establishment and operation of trusted production networks (Kayikci et al., 2022; Lohmer & Lasch, 2020). As a result, collaboration may become a more competing and prevalent paradigm. Previous studies particularly found a link between CE and digitalisation in the development of new technological tools to promote the establishment of industrial symbiosis among enterprises interested in incorporating sustainable practices into their business models (Pizzi et al., 2021).
- **Supporting waste management (R3)**: Blockchain-based platforms are highly recommended for use in the CSC, particularly by SMEs involved in waste management for firms belonging to complex industries (Centobelli et al., 2022). Blockchain also facilitates hazardous waste monitoring by apportioning accountability across all parties involved (Varriale et al., 2020). Specifically, smart contracts can simplify waste exchanges by automatically carrying out operations according to criteria such as waste condition, quantity, and volume (Ajwani-Ramchandani et al., 2021; Kouhizadeh et al., 2019). In addition, tracking devices and sensors can pinpoint the location of waste and record the information on the blockchain (Kouhizadeh et al., 2019). As a result, this will considerably enhance environmental safety, increase social responsibility and reduce fraud (Mercuri et al., 2021).
- **Strengthening collaboration and coordination (R4)**: Blockchain has emerged as a generally acknowledged transformative technology owing to its many advantages, including ease of collaboration and coordination for organisations (Rejeb, Keogh, et al., 2021). As such, blockchain can support several CSC processes by collecting and sharing information across all links in the supply chain while fostering socio-environmental sustainability (Nandi et al., 2020). The use of blockchain can strengthen inter/intra-relationships among CSC stakeholders and provide access to the necessary information to promote creativity, knowledge sharing and entrepreneurial innovation (Adel & Younis, 2021). Prause and Boevsky (2019) note that blockchain, in conjunction with smart contract solutions, can stimulate entrepreneurial collaborations in logistics and CSC networks, even across international boundaries. As a result, SMEs can benefit from forming partnerships and exchanging know-how to compete successfully in the marketplace (Varriale et al., 2021).
- **Providing end-to-end traceability (R5)**: In a CSC, blockchain can be used to monitor the flow of circular products from their initial source of raw materials to the final customer (Kumar Bhardwaj et al., 2021). Cost, quality, date, location, certification and other relevant data can be recorded and stored in blockchain for efficient management of the distributed CSC network (Ghode et al., 2021). As a result, organisations can capitalise on the acquired information to determine that components and products have less value for circularity purposes (Kouhizadeh et al., 2019). Customers can also verify the authenticity and the sustainability of raw materials and the legitimacy of all transactions along CSC processes with the support of blockchain (Kayikci et al., 2022). Consequently, CSC partners can reduce costs related to conventional tracking approaches, reduce fraud (Mohit et al., 2021) and develop product biographies via information synchronisation and the coordination of the CSC networks (Narayan & Tidström, 2020).

- **Alleviating financial problems (R6)**: Financing a sustainable and CE is an important area where digital technologies promise to bring value, especially for SMEs and new ventures that have greater trouble gaining access to capital than larger enterprises (Pizzi et al., 2021). In this regard, the emergence of blockchain technology has the potential to solve several problems that have plagued traditional credit management systems (Ashley & Johnson, 2018). The technology not only eliminates various transaction fees often involved with financing start-ups but also provides investors and start-up founders more control over the development and financing process of businesses (Ahluwalia et al., 2020). For example, tokenisation of the underlying project or product can be implemented using blockchain technology, and the general public can buy these tokens via crowdfunding campaigns (Stemler, 2013). As a result, blockchain has the potential to reduce capital costs while simultaneously increasing the scale and speed with which investors are matched with investment opportunities (Pizzi et al., 2021). The blockchain-enabled financing system can lead to more decentralised and effective entrepreneurial financing processes (Ahluwalia et al., 2020).
- **Supporting product deletion strategies (R7)**: Taking an existing product off the market is known as product deletion, and it can be implemented either at the product or product variety level (Kouhizadeh et al., 2019). With its ability to record and verify information about products and services, blockchain technology can aid in the deletion management of unwanted products (Zhu et al., 2021; Zhu & Kouhizadeh, 2019). A product's quality and recyclability, as well as its location and present stage in the product life cycle, are all aspects that can be reliably collected and stored in blockchain ledgers. Thus, this allows organisations to track products, examine their durability and performance and pinpoint any weak spots. By allowing for the tracking of products and raw materials back to their source and the circulation of energy consumption measurements, blockchain can also facilitate the detection of energy issues and the implementation of efficient product deletion policies (Centobelli et al., 2022). Energy-intensive and inefficient products can be deleted to benefit the CSC and advance the CE agenda (Kouhizadeh et al., 2019). Appropriately taxing products with low energy performance is another way for policymakers to benefit from blockchain, thereby internalising the external costs of energy use and emissions (Kouhizadeh et al., 2019).
- **Strengthening the competitive advantage of circular economy business models (R8)**: Blockchain paves the way for the emergence of new markets while providing market players with the opportunity to reduce the auditing costs of transaction information (Catalini & Gans, 2020). CSC participants on the network can check the status of any transaction with a simple query, thanks to the blockchain's mix of incentives and cryptography (Narayan & Tidström, 2020). Moreover, SMEs can use blockchain to strengthen their circular business models and gain a competitive advantage. According to Philipp et al. (2019), the distributed and decentralised nature of blockchain has the potential to increase the competitiveness and efficiency of SMEs by improving their access to information, decreasing their exposure to risks and lowering the number and cost of intermediaries. As a result, the removal and reduction of information intermediaries are particularly beneficial for small and entrepreneurial players, thereby increasing their process efficiency and competitiveness (Adel & Younis, 2021; Philipp et al., 2019).
- **Information and knowledge sharing (R9)**: Peer-to-peer business operations can be facilitated by blockchain technology, which, in comparison to traditional technologies, can deliver more symmetrical information to CSC partners (Rejeb, Keogh, et al., 2021). With blockchain technology, all CSC participants can rely on a trusted unified repository of authoritative data that can be utilised to facilitate the seamless exchange of verified information in real-time, ultimately leading to improved communication, cooperation and transparency (Centobelli et al., 2022; Kouhizadeh et al., 2019; Wang et al., 2020). In the medium and long term, blockchain performs a vital role in eliminating perishable and mismanaged products from accessing buyers (Kayikci, Durak Usar, & Aylak, 2021). Moreover, the pooling of resources and insights on a blockchain enables organisations to better align their values, beliefs and practices with CE efforts (Kayikci et al., 2022). Ghode et al. (2021) highlight that organisations can develop a multi-echelon CSC system with blockchain, which helps coordinate information and overcome the bullwhip effect. The transparency of blockchain contributes to the enhancement of CSC activities by providing organisations with critical knowledge regarding product life cycles. Similarly, the transparency and security features of blockchain make it a promising solution for the long-term viability of SMEs as the technology automates business operations and optimises returns. Overall, blockchain provides a means to better oversee information sharing and prevent human rights abuses in CSC, including child labour, inhumane working conditions, extortion and corruption (Varriale et al., 2020).
- **Supporting clean energy products (R10)**: The increasing demand for blockchain solutions has prompted innovation in green and renewable energies (Ashley & Johnson, 2018). The efficiency of energy markets can be further improved by the use of cryptocurrencies and the trustworthiness of information provided by blockchain technology (Kouhizadeh et al., 2019). CSC stakeholders and governmental authorities can use blockchain to analyse data from the energy markets and monitor their compliance with environmental targets (Manea et al., 2021). The accurate data given on blockchain ledgers can also improve the ability to track and evaluate materials and products' energy consumption in real-time (Kouhizadeh et al., 2019).
- **Supporting trading activities (R11)**: Blockchain's ability to eliminate middlemen paves the way for whole new ways of trading and exchanging products and services (Lohmer & Lasch, 2020). According to Benstead et al. (2022), blockchain has the potential to reduce transactions influenced by the unpredictability of business partners' behaviour. The authors advocate the utility of blockchain to lessen the financial burden of verifying identities, collecting data and assessing possible trading partners. Moreover, trading costs related

to monitoring suppliers can be significantly reduced, and dispute resolution can be made easier with blockchain because the technology provides real-time, transparent and verifiable information flows between trading parties (Rejeb, Rejeb, et al., 2021). Katsikouli et al. (2020) show that Danish SMEs can gain from deploying blockchain systems due to their ability to promote authenticity and fair trade. As a result, the implementation of blockchain in CSC can drastically streamline even the most complicated trading settings.

- **Improving process efficiency (R12)**: Implementing blockchain technology is a powerful tool for enforcing the necessary process redesigns in the CSC to ensure the integrity of digital data and propel digital transformation (Hackius & Petersen, 2020). Rather than relying on a single authority to oversee multiple transactions, blockchain technology allows for decentralised CSC activities (Kayikci et al., 2020). Blockchain, as proposed by Bai and Sarkis (2020), satisfies the necessary conditions for allowing efficient CSC integration. Positive economic outcomes can be achieved through the strategic implementation of blockchain technology in CSC by enabling cost-efficient and faster transactions (Rejeb, Rejeb, et al., 2021), minimising bureaucracy, paperwork and risks of human mistake (Srivastava et al., 2019); facilitating accurate record keeping; and strengthening customer confidence (Benstead et al., 2022). In conclusion, the CSC can accomplish data synchronisation and reduce the resources needed to check the process status with the deployment of blockchain, which accelerates disintermediation and process automation via the use of smart contracts (Philipp et al., 2019).

4.2 | Circular blockchain start-ups

In this section, the circular blockchain start-ups are selected in the concept of QCA and analysed in terms of their roles to transition to CSC. As the steps are explained in Section 3.2, the first step was to develop a theory. In this context, theory of change is considered in terms of MLP approach and disruptive innovation approach that is explained in detail in Section 2.2. Second step of QCA is to identify the start-ups. Since cases are frequently built around a particular conclusion or theory of concern, case selection is purposeful based on theory rather than random (Regan, 2017). Thus, the cases are chosen purposively to demonstrate a specific ‘result’ of relevance based on the research question. As the third step, the set of blockchain roles is defined as presented in Section 4.1. In this section, it is aimed to explain the verification of the blockchain roles identified by previously explained SLR.

A total of 34 blockchain start-ups with support of CE practices were initially detected by extensive internet search. Six circular blockchain start-ups out of them were selected and analysed to prove these roles. In this context, they are selected based on the relevance to assess the roles of blockchain in the identified case studies in terms of a CSC transition. The information about these companies was collected from various sources, as seen in Table 3. For the calibration process, which corresponds to the fourth step of QCA, crisp-set QCA is preferred to validate the blockchain roles by analysing the documentation related to the start-ups. The six experts were selected based on their expertise in various fields related to CSC and blockchain technology. The panel includes two university professors, two CSC experts and two blockchain experts. To ensure the validity of the data collected from these experts, rigorous validation was conducted. This process involved a pilot study where the experts were asked to review and validate the roles identified and the questionnaire. In addition, the experts were provided with detailed instructions on how to complete the questionnaire and were given the opportunity to ask questions or seek clarification. Once the evaluation process was completed, the selected start-ups were analysed by applying QCA, and their relationship to the 12 identified fundamental roles of blockchain entrepreneurship in the CSC transition was discussed and verified by expert consensus. The experts provided valuable insights into the roles played by blockchain start-ups in the CSC transition, and their feedback was used to refine and improve the analysis. The results of QCA are demonstrated in Table 4. In the end, all identified roles retrieved from SLR were accepted for this study. Below, the concept of each start-up and their relationship to the identified roles are explained in more detail.

4.2.1 | BanQu: Traceable, transparent, and auditable supply chains

BanQu was founded in Minneapolis, Minnesota in 2015. BanQu's digital automated supply chain tracing and transaction interfaces leverage blockchain technology to track recycled waste along the value chain. Thus, BanQu advocates the CE to guarantee transparent as well as unbiased supply chains (BanQu, 2021). As supporters of circularity, both groups have joined forces to financially strengthen recycling collectors while also ensuring optimal recyclable wastes value chain. BanQu's programme offers both socioeconomic and environmental advantages by ensuring that all transactions in a value chain are documented on a blockchain (Marchant, 2021). As a result of QCA, the start-up verifies R1, R3, R5, R6, and R9.

4.2.2 | ChemChain: Track chemicals along the value chain

ChemChain is a blockchain platform established in Rotterdam, Netherlands in 2019. It is intended for implementation by the chemical industry to convey information about chemicals in goods from chemical makers to consumers, recyclers, and waste operators throughout the value chain by enabling CE models (ChemChain, 2020). As there is a high market need for product transparency throughout their life cycle to meet present legislative requirements and growing CE concerns, the EU-funded ChemChain project helps the industry by developing a dependable and widely acknowledged open-source blockchain infrastructure for storing, exchanging, building and tracking chemical-related data along the value chain (Cordis, 2020). QCA of ChemChain verified R1, R2, R3, R5, R7, R8, and R9.

TABLE 3 Selected circular blockchain cases and sources

Start-ups	Industries	Document type	Business cases	The role of blockchain entrepreneurship	CE principles	Supporting CE activities
BanQu https://banqu.co/	Agriculture/ Food	Publications, press and others	Coca-Cola Africa, track and trace recycled material across the value chain	R1 (Supporting CE practices), R3 (Supporting waste management), R5 (Providing end-to-end traceability), R6 (Alleviating financial problems), R9 (Information and knowledge sharing)	Recycle Reuse	• Recycle and reuse bottles and cans, • Ensuring the economic well-being of recycling collectors/ waste pickers, • Financial app integrations, • Providing price transparency for both buyers and sellers.
ChemChain https://chemcha.in/	Chemical	Publications, press and others	Dow Polyurethanes RENUVA™ mattress recycling programme	R1 (Supporting CE practices), R2 (Supporting the development of industrial symbiosis), R3 (Supporting waste management), R5 (Providing end-to-end traceability), R7 (Supporting product deletion strategies), R8 (Strengthening the competitive advantage of circular economy business models), R9 (Information and knowledge sharing)	Recycle Reuse Recover	• Mattress foam recycling, • Mattress recycling programme, • Polyurethane-based products, • The precise know to recover or if the product is recycled or biodegradable.
Circularise https://www.circularise.com/	Plastic	Publications, press and others	Neste, Finnish oil refiner provides transparency for its renewable polymers and chemicals. Plastic traceability	R1 (Supporting CE practices), R2 (Supporting the development of industrial symbiosis), R3 (Supporting waste management), R4 (Strengthening collaboration and coordination), R5 (Providing end-to-end traceability), R6 (Alleviating financial problems), R10 (Supporting clean energy products)	Recycle	• A powerful group of firms to establish an industry standard for openness in areas such as recycled content and other sustainable activities, • The Alliance to End Plastic Waste selected Circularise for an accelerated programme.
EverLedger https://everledger.io/	Manufacturing	Publications, industry reports, press and others	Global Battery Alliance, Battery Passport and tracing the life cycle of lithium-ion batteries	R1 (Supporting CE practices), R7 (Supporting product deletion strategies), R8 (Strengthening the competitive advantage of circular economy business models), R9 (Information and knowledge sharing), R11 (Supporting trading activities), R12 (Improving process efficiency)	Recycle Reuse Repurpose	• Lifecycle management of batteries, • Reuse and recycle batteries, • Leading battery development.
MonoChain				R1 (Supporting CE practices),	Reuse	• Targeting for textile waste,

TABLE 3 (Continued)

Start-ups	Industries	Document type	Business cases	The role of blockchain entrepreneurship	CE principles	Supporting CE activities
https://monochain.org/	Apparel fashion/ Clothes	Publications, industry reports, press and others	Loopster Luxe, empowering brands and retailers to adopt a sustainable circular economy-driven practice,	R2 (Supporting the development of industrial symbiosis), R3 (Supporting waste management), R5 (Providing end-to-end traceability), R7 (Supporting product deletion strategies), R8 (Strengthening the competitive advantage of circular economy business models), R9 (Information and knowledge sharing), R10 (Supporting clean energy products) R12 (Improving process efficiency)		• After-purchase authentication for products, • Reuse by selling or donating unwanted apparel.
RemediChain https://www.donatemymeds.org/	Medical	Publications, industry reports, press and others	Good Shepherd Pharmacy, donation and disposal of surplus medication from individuals	R1 (Supporting CE practices), R2 (Supporting the development of industrial symbiosis), R3 (Supporting waste management), R5 (Providing end-to-end traceability), R6 (Alleviating financial problems), R7 (Supporting product deletion strategies), R8 (Strengthening the competitive advantage of circular economy business models), R9 (Information and knowledge sharing)	Recycle Reuse	• Medication recycling programme for reclaiming medicines and tracking prescription waste, • Surplus drugs for donation.

TABLE 4 QCA analysis of the start-ups

	The roles of blockchain entrepreneurship in CSC transition											
Start-ups	R1	R2	R3	R4	R5	R6	R7	R8	R9	R10	R11	R12
BanQu	1	0	1	0	1	1	0	0	1	0	0	0
ChemChain	1	1	1	0	1	0	1	1	1	0	0	0
Circularise	1	1	1	1	1	1	0	0	0	1	0	0
EverLedger	1	0	0	0	0	0	1	1	1	0	1	1
MonoChain	1	1	1	1	0	0	1	1	1	1	0	1
RemediChain	1	1	1	0	1	1	1	1	1	0	0	0
Verification of roles	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

4.2.3 | Circularise: End-to-end supply chain traceability

Circularise was founded in Den Haag, South Holland in 2016. Circularise is a blockchain-based transparency system that provides definitive verification for manufacturers' CE, sustainability and recycling activities at each stage of the value chain (Circularise, 2022). Circularise provides value chain transparency without requiring datasets or supply chain partners to be disclosed. The platform tracks material properties of items that cannot be distinguished by dismantling the product, such as whether and in what percentage recycled materials were used (Circularise, 2022). The technology employs a virtual currency and a chemical tracer to provide supply chain transparency and material certification (Circularise, 2022). Circularise was approved into the Alliance to End Plastic Waste's accelerator programme as a consequence of the cooperation. Because petrochemicals account for 12% of total oil consumption, the start-up also promotes clean energy solutions (LedgerInsights, 2022). As a result, the roles verified are R1, R2, R3, R4, R5, R6, and R10.

4.2.4 | Everledger: Digital transparency

Everledger was founded in Clerkenwell, London in 2015. For manufacturers and retailers, the Everledger Platform helps with demand development, sustainability and safety. The Everledger platform enables the insurance sector to work more efficiently and improves the service by providing more reliable information (EverLedger, 2021). The aim of the start-up is to provide better openness and assurance in markets where visibility is most important in such sectors as from diamonds to fine wines. Buyers and sellers of any product in a variety of sectors can currently deal with trust and provide better customer service to the final consumers with the enterprise-grade blockchain platform. Both automotive and battery manufacturers may use the Everledger platform (Toto, 2021) to trace and confirm downstream battery re-use, repurposing, as well as recycling activities (EverLedger, 2021). As a result of QCA, the start-up verifies R1, R7, R8, R9, R11, and R12.

4.2.5 | MonoChain: Leaders in re-sale and sustainable fashion

Businesses must adapt in order to transition to CE efficiently, and there is a need for new and disruptive business models and technology to facilitate the transition (MonoChain, 2019). MonoChain, a London-based start-up, is working to reduce textile waste by using a blockchain-powered system that offers product authenticity after the sale (TextileToday, 2020). MonoChain's unique blockchain technology is capable of combining primary and secondary markets, promoting reuse and extending product life cycles, with the goal of drastically changing customer and production behaviour (MonoChain, 2019). The start-up verifies the roles that are R1, R2, R3, R5, R7, R8, R9, R10, and R12.

4.2.6 | RemediChain: Donate unused medication

RemediChain is a technological start-up based in Memphis, Tennessee that was founded in 2018 (Briones, 2020). RemediChain aims to leverage blockchain to reclaim abandoned, high-value pharmaceuticals from patients and distribute them to economically disadvantaged patients who would not be able to pay for medications on a routine basis (Brignac, 2021). RemediChain is a platform that encourages individuals to donate and dispose of excess medicine (Brignac, 2021). The blockchain serves as a 'single source of truth' for excess medicine, guaranteeing that provided drugs are assigned to individuals in need and outdated medicines are appropriately discarded (Briones, 2020). Thus, the roles verified as the result of QCA are R1, R2, R3, R5, R6, R7, R8, and R9.

4.3 | Causal relationships

To provide the answer for RQ2, this section analyses the causal relationships between these roles of blockchain entrepreneurship in the CSC transition. An expert committee is formed of five specialists based on their established knowledge and degree of experience as Kayikci, Kazancoglu, et al. (2021) suggested. All experts are blockchain entrepreneurs. They have expertise in both blockchain technology and circular applications in different supply chains. They have an average of 10 years of work experience and hold master's degrees. The Fuzzy-DEMATEL approach was used to cope with the ambiguity and indecisiveness of humanistic ideas of the participants' opinions. The fuzzy linguistic scale was employed to translate the acquired fuzzy data into linguistic values following getting survey answers from specified experts, as seen in Table 2. Firstly, during constructing the initial relationship matrix, the arithmetic means of the experts' evaluations and the areas they regarded acceptable were acquired as seen in Table 5.

Later, the total relation matrix was developed by multiplying the degrees of C and R values in Table 6. The causal diagram is established following completing all of the Fuzzy-DEMATEL phases, as shown in Figure 2. Table 7 displays prominence and relation axis for the causal diagram. The cause criteria can be determined as R5 (Providing end-to-end traceability), R6 (Alleviating financial problems), R8 (Strengthening the competitive advantage of circular economy business models), R9 (Information and knowledge sharing), R10 (Supporting clean energy products) and R12 (Improving process efficiency). Furthermore, the effect criteria are R1 (Supporting CE practices), R2 (Supporting the development of industrial symbiosis), R3 (Supporting waste management), R4 (Strengthening collaboration and coordination), R7 (Supporting product deletion strategies) and R11 (Supporting trading activities).

Considering the causal diagram, (R + C) and (R − C) values are discussed further. For (R + C), the cause group, R9 (Information and knowledge sharing) has the highest level with 8.69. Then, R4 (Strengthening collaboration and coordination) is the second role with 8.51. R1 (Supporting CE practices) comes next with 8.26. As the fourth, R5 (Providing end-to-end traceability) is 8.22. Moreover, for (R − C), the highest value is 0.78 for R12 (Improving process

TABLE 5 Initial direct relation matrix

	R1	R2	R3	R4	R5	R6	R7	R8	R9	R10	R11	R12	Total
R1	0.00	0.55	0.64	0.87	0.78	0.31	0.59	0.69	0.83	0.45	0.45	0.69	6.85
R2	0.64	0.00	0.64	0.59	0.69	0.30	0.45	0.50	0.73	0.35	0.64	0.55	6.09
R3	0.59	0.69	0.00	0.73	0.64	0.69	0.45	0.50	0.50	0.31	0.41	0.50	6.01
R4	0.83	0.78	0.59	0.00	0.69	0.50	0.50	0.64	0.78	0.59	0.55	0.69	7.13
R5	0.73	0.64	0.83	0.78	0.00	0.50	0.41	0.87	0.78	0.50	0.64	0.83	7.51
R6	0.59	0.59	0.31	0.64	0.21	0.00	0.27	0.59	0.50	0.21	0.59	0.31	4.82
R7	0.35	0.24	0.49	0.14	0.19	0.03	0.00	0.35	0.45	0.35	0.43	0.39	3.41
R8	0.78	0.69	0.59	0.87	0.64	0.50	0.50	0.00	0.69	0.45	0.50	0.55	6.76
R9	0.87	0.78	0.73	0.87	0.83	0.69	0.64	0.83	0.00	0.64	0.50	0.69	8.07
R10	0.59	0.64	0.45	0.69	0.50	0.05	0.50	0.31	0.59	0.00	0.40	0.50	5.23
R11	0.64	0.64	0.41	0.69	0.55	0.64	0.27	0.41	0.45	0.21	0.00	0.26	5.15
R12	0.83	0.73	0.69	0.83	0.92	0.50	0.64	0.50	0.83	0.45	0.50	0.00	7.41
											MAX		8.07

TABLE 6 Total relation matrix

	R1	R2	R3	R4	R5	R6	R7	R8	R9	R10	R11	R12
R1	0.32	0.36	0.35	0.42	0.38	0.25	0.30	0.35	0.40	0.25	0.29	0.34
R2	0.35	0.26	0.32	0.36	0.34	0.22	0.25	0.30	0.35	0.22	0.29	0.29
R3	0.34	0.34	0.24	0.37	0.32	0.26	0.25	0.29	0.32	0.21	0.26	0.28
R4	0.42	0.39	0.35	0.34	0.38	0.27	0.29	0.35	0.40	0.27	0.31	0.35
R5	0.43	0.40	0.39	0.44	0.31	0.29	0.29	0.39	0.42	0.28	0.33	0.38
R6	0.29	0.28	0.23	0.30	0.23	0.15	0.19	0.26	0.27	0.17	0.24	0.22
R7	0.20	0.18	0.20	0.18	0.17	0.11	0.12	0.18	0.21	0.14	0.17	0.18
R8	0.40	0.37	0.34	0.42	0.36	0.26	0.28	0.26	0.38	0.25	0.29	0.32
R9	0.46	0.43	0.40	0.47	0.42	0.32	0.33	0.40	0.35	0.30	0.33	0.38
R10	0.31	0.30	0.27	0.33	0.28	0.17	0.23	0.24	0.30	0.16	0.23	0.26
R11	0.31	0.30	0.26	0.32	0.28	0.23	0.20	0.25	0.28	0.18	0.18	0.23
R12	0.43	0.40	0.37	0.44	0.41	0.28	0.32	0.35	0.42	0.27	0.31	0.28

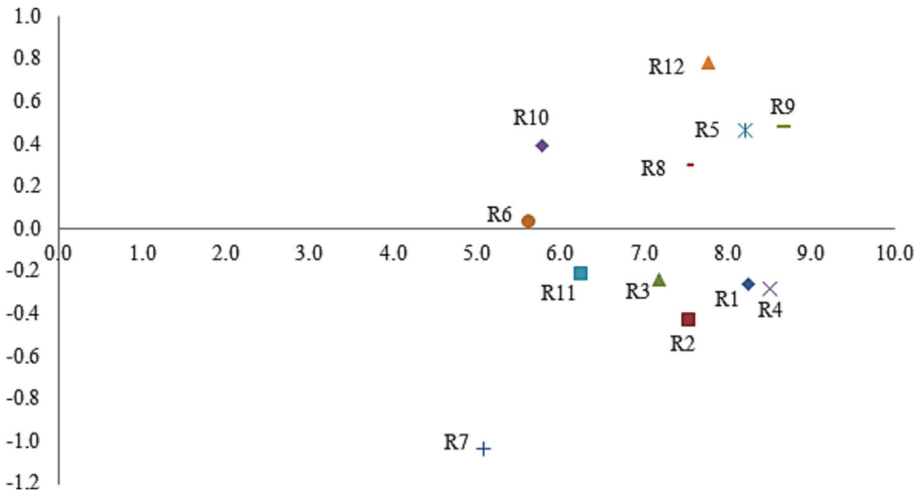

FIGURE 2 The causal diagram.

TABLE 7 Prominence and relation axis for the causal diagram

	R1	R2	R3	R4	R5	R6	R7	R8	R9	R10	R11	R12
C	4.3	4.0	3.7	4.4	3.9	2.8	3.1	3.6	4.1	2.7	3.2	3.5
R	4.0	3.6	3.5	4.1	4.3	2.8	2.0	3.9	4.6	3.1	3.0	4.3
R + C	8.3	7.6	7.2	8.5	8.2	5.6	5.1	7.5	8.7	5.8	6.3	7.8
R − C	−0.3	−0.4	−0.2	−0.3	0.5	0.0	−1.0	0.3	0.5	0.4	−0.2	0.8
	E	E	E	E	C	C	E	C	C	C	E	C

efficiency). Next, R9 (Information and knowledge sharing) is the second highest value with 0.48. The third role is R5 (Providing end-to-end traceability) with 0.47. Also, R10 (Supporting clean energy products) is the next role with 0.39.

As Table 7 demonstrates, the degree of influence impact (R), R9 (Information and knowledge sharing) has the highest level with 4.6. Thus, R9 is the most influencing criterion, among others. Moreover, the degree of influential impact C displays the criterion that has an effect on other causal factors. R4 (Strengthening collaboration and coordination) has the highest value of C with 4.4. R1 (Supporting CE practices) is the next role with 4.3.

5 | DISCUSSION

Blockchain start-ups perform a critical position in facilitating the alteration from a linear to CE and in fostering the growth of CSCs. The purpose of this paper is to evaluate circular blockchain start-ups to investigate the role of blockchain entrepreneurship in the transformation to CSC. This study contributes to the literature by reviewing the literature and start-ups to provide confirmed roles of blockchain entrepreneurship in the adaptation to CSC. A further contribution is the examination of the causal interconnections among the roles. According to the results, blockchain provides 12 roles in enabling the shift from linear to CE while also boosting the growth of CSCs. Despite the range of new technologies linked with CSC (Chari et al., 2022; Di Maria et al., 2022; Kayikci, Kazancoglu, et al., 2021; Khan, Razzaq, et al., 2021;Yu et al., 2022), blockchain is gaining prominence due to its capacity for efficient information sharing, practicality and unique attributes such as immutability, security, traceability, transparency and integration of smart contracts in CSC operations (Kouhizadeh et al., 2021, 2020; Rejeb et al., 2019). To fully exploit blockchain's potential in CSC, it is crucial to identify and evaluate the roles of the technology to pave the way for a successful implementation roadmap. However, no prior work has examined the role of blockchain entrepreneurship in developing CSC and establishing a technological foundation that enhances CSC sustainability and performance.

Based on the results, 'information and knowledge sharing' (Kouhizadeh et al., 2022; Shojaei et al., 2021; Narayan & Tidström, 2020; Kouhizadeh & Sarkis, 2018) is the most influencing role, among others. Information sharing is regarded as a critical facilitator in the effort to develop CSCs and advance the CE agenda (Fang et al., 2021; Kamal et al., 2022; Khan & Abonyi, 2022) since CE stakeholders need access to sufficient data about the products and the activities of other parties to keep materials and products in circulation. Blockchain technology can play a critical role in facilitating information and knowledge-sharing processes (Rejeb, Keogh, et al., 2021).

Blockchain provides a secure and transparent platform for sharing data and information among stakeholders, thereby promoting more informed decision-making and enhancing collaboration and coordination within CSC (Chaouni Benabdellah et al., 2023; Elghaish et al., 2023). By leveraging blockchain's capabilities, stakeholders can share information about best practices, innovations, and successes, thereby promoting learning and identifying opportunities to improve their own practices (Rejeb, Keogh, et al., 2021). With the support of the technology, stakeholders can work together to optimise resource utilisation, reduce waste and achieve the overarching goals of the CE. For example, manufacturers can use feedback on how customers use their products to improve features such as longevity and recycling rates (Kouhizadeh et al., 2020). Providers of maintenance services, for instance, can improve the quality of their work by learning more about the wear and tear of the products they serve. Moreover, with knowledge about product composition and disassembly methods, recyclers and remanufacturers can better and more precisely target materials for recycling and products for remanufacturing. Consistent with Bai and Sarkis (2020), blockchain plays a critical role in fostering sustainability, which benefits organisations through increased information sharing and transparency and improves CSC collaboration. Carbon footprints in CSC activities can be greatly reduced with the support of blockchain's ability to ensure accurate and real-time exchange of information. By pooling resources and sharing information via blockchain, firms can better combat concerns of product counterfeiting and fraud and strengthen the confidence of their customers. With the increased information sharing and transparency provided by blockchain, firms can also determine which of their waste streams can be converted into a useful by-product or whose environmental impact can be mitigated (Rose & Stegemann, 2018; Yadav et al., 2020).

The information-sharing capability of blockchain can enable organisations to create customised products and develop new features that optimise product performance. Rejeb, Suhaiza, et al. (2022) argue that firms can exchange data and information about their products and processes, including their raw materials, components and manufacturing methods. This enables firms to collaborate with other entities in the CSC, including customers, suppliers and other business partners, to develop products that meet specific needs and requirements. By exchanging this information, Kayikci et al. (2022) state that firms can identify opportunities to optimise their product designs, reduce waste and enhance the circularity of their products. For example, a firm producing electronic products can leverage blockchain to share information about the materials used in the manufacturing products, including the source of raw materials and their environmental impacts. By sharing this information with suppliers and other business partners in the CSC, the firm can identify opportunities to use more sustainable and circular materials in their products, such as recycled metals or plastics. As a result, this can aid firms in improving product circularity and reducing environmental impacts (Saberi et al., 2019). Furthermore, information sharing via blockchain can contribute to sustainable product usage and performance. As such, the technology enables firms to collaborate to identify new opportunities regarding product functionality and durability. The information shared on blockchain can inspire CSC stakeholders to develop new features, such as predictive maintenance or energy-saving modes (Mastos et al., 2021; Zheng et al., 2021), that maximise the performance and longevity of products.

Moreover, 'strengthening collaboration and coordination' is the most causal role (Kayikci et al., 2022; Nandi et al., 2021; Pakseresht et al., 2022). It has been suggested by prior research (e.g., Mishra & Tyagi, 2019) that collaboration is essential for creating CSCs to reduce, postpone and close the loops of resources and materials in the ecosystem. CSCs need different forms of collaboration and coordination mechanisms than traditional supply chains. Therefore, firms should innovate and invest in innovative technologies, including blockchain, to improve the efficacy of their current information systems, streamline information-sharing processes and facilitate the integration of CE practices in the CSC. Blockchain's ability to serve as a hub for all CSC-related parties to collaborate and communicate efficiently and openly. Blockchain improves CSC stakeholder participation and supply chain monitoring (Kouhizadeh et al., 2021). Various CSC players can contribute to data collection, validation, and use of product life cycle information in blockchain (Böckel et al., 2021). In addition, the technology encourages more actors of the CSC to participate in circularity initiatives, which can help reduce or even remove potential implementation barriers to the CSC (Rejeb, Zailani, et al., 2022). Each participant in the CSC has faith in the honesty and integrity of the other participants. As a result of this trust and confidence, the CSC can boost its responsiveness in terms of networking. The distributed nature of blockchain pushes the CSC towards a higher degree of openness, which enhances transparency, reduces information distortion and increases transactional velocity (Kayikci et al., 2022). The operations associated with the 'closing of the loop' can include a number of firms and possibly cross-sector partnerships. For CE practices to be implemented efficiently and effectively in the CSC, blockchain consortia can improve communication, coordination and standardisation. Incorporating blockchain into the CSC can improve resource management by encouraging creative closed-loop systems, bolstering resource control and promoting cooperation among business stakeholders. Thus, blockchain's transparency can facilitate fruitful organisational cooperation as the technology has the potential to reduce inefficiencies within CSC networks, efficiently arrange the loops of production and consumption, and eventually 'supporting CE practices' (i.e., the third causal role) (Kouhizadeh et al., 2022).

In CSCs, the aim is to maximise resource efficiency by extending the life cycle of products through reuse, refurbishment or recycling. To achieve this goal, it is crucial to track the movement of materials and products through the entire supply chain. Blockchain technology can enable end-to-end CSC traceability by creating a tamper-proof record of all transactions and movements of products and materials (Kayikci et al., 2022). According to Kouhizadeh et al. (2020), this record includes all relevant information regarding the product's history, including its origin, ownership, condition, and location. Access to this information enables firms to ensure that products are reused or recycled according to CE principles rather than disposed of after a single use. Thus, this can lead to a reduction in waste and more sustainable use of resources. Moreover, increased end-to-end CSC traceability can support firms in devising effective product recovery strategies, such as reuse, recycling, and remanufacturing (Centobelli et al., 2022; Huang et al., 2022). With blockchain, tracking the entire lifecycle of materials and products can clarify the social and environmental conditions that may pose risks to health, safety, and the environment. The technology allows for easy tracking of the state of each material, product, or component in the CSC, making it possible to proactively plan for product reusability. Additionally, previous studies demonstrate that companies can capitalise on blockchain to monitor greenhouse gas emissions and establish arrangements for recognising environmental impacts (Upadhyay et al., 2021). For example, blockchain can be combined with other technologies, such as the Internet of Things (IoT), to collect and store data on emissions in a decentralised and immutable ledger. This enables greater transparency and accuracy in measuring emissions in CSC and facilitates the development of carbon credit or other incentives for reducing emissions (Kouhizadeh & Sarkis, 2018).

Blockchain can also be used to identify CSC areas for improvement and implement more sustainable practices. For instance, the technology can be used to track the use of renewable energy sources, which fosters environmental sustainability and helps firms meet their sustainability goals while also building trust and accountability with CSC stakeholders. Finally, the potential of blockchain for improved traceability can also be leveraged to mitigate the risks associated with human rights and child labour in manufacturing and supply chain operations. When integrated with other advanced technologies and sensor devices, analytical science methods, supply chain surveillance, and surprise supplier audits, blockchain can significantly contribute to the rising trend of environmental, social, and governance measures, thereby promoting sustainable CSC practices across industries.

As we look further at the results, it was determined that the roles of R1, R2, R3, R4, R7, and R11 were affected roles. When the results are examined, the effect roles with the highest values are R3 and R11. When these roles are focused, results are provided for the CSC transaction in the short term. In terms of Supporting waste management (R3), blockchain-based systems are strongly advised for adoption in the CSC, notably by SMEs responsible for waste management for enterprises in complicated sectors (Centobelli et al., 2022). Blockchain, therefore, improves toxic disposal tracking easier by dispersing credibility throughout all entities engaged (Varriale et al., 2020). Moreover, the next effect role is Supporting trading activities (R11). On the other hand, Katsikouli et al. (2020) show that the capacity of blockchain technology to encourage integrity and fair trade can benefit Danish SMEs. As a result, the adoption of blockchain in CSC may greatly simplify even the most complex trading scenarios. Furthermore, effect roles are immediately changed by other roles, and they are easier to attain since they produce more obvious short-term consequences than causal roles. In addition, it was concluded that the causing roles were R5, R6, R7, R8, R9, R10, and R12. When these results are examined, it is noteworthy that Improving process efficiency (R12) is the most causing role. Blockchain, as presented by Bai and Sarkis (2020), meets the requirements for effective CSC transformation. Positive economic effects may be obtained by strategically implementing blockchain technology in CSC by allowing cost-effective and smoother operations (Rejeb, Rejeb, et al., 2021), reducing complexity, paperwork, and the danger of human error (Srivastava et al., 2019), enabling proper record keeping and increasing consumer trust (Benstead et al., 2022).

5.1 | Theoretical contributions

This study is based on theory of change. Within the scope of this theory, the roles of blockchain entrepreneurship for the CSC transition process are discussed. MLP and disruptive innovation approaches are considered in the content of this theory. The MLP approach assists in understanding how innovations in a society thrive and, as a result, how diverse socio-technical systems develop over time. Disruptive innovation is the process through which a product or service first positions itself at the bottom of a sector, typically by being cheaper in price and more abundant, and then progressively climbs, finally replacing established competitors. Both approaches help to better understand the roles of blockchain entrepreneurship's CSC transition process.

This study represents one of the pioneering attempts to examine the role of blockchain entrepreneurship in supply chain management, with a specific focus on the CSC. Blockchain technology and CSC are both burgeoning fields that have significant implications for both academia and industry (Huang et al., 2022; Kayikci et al., 2022; Kouhizadeh et al., 2020). The current study has successfully integrated these two concepts, yielding valuable insights. Blockchain technology offers unique and incomparable advantages, including efficient information sharing, strong collaboration and coordination, end-to-end CSC traceability, and process efficiency. While previous research examining the relationship between blockchain technology and the CSC has primarily focused on the potential of adopting blockchain technology to improve CSCM and the CE proposing different frameworks or methods for achieving this goal (Centobelli et al., 2022; Gong et al., 2022; Huang et al., 2022), there is still a need for further exploring and evaluating the roles of blockchain entrepreneurship in the transition to CSCs. From the theoretical perspective, the use of Fuzzy–DEMATEL represents a novel approach that offers a more accurate and rigorous way of identifying the critical roles of blockchain entrepreneurship in CSCs. By using this approach, this study is able to identify not only the individual roles but also the interdependencies and relative importance of each role. This helps to provide a more comprehensive understanding of the roles of blockchain that accelerate the transition to CSCs. The findings of the study can be used as a valuable guide for practitioners in ensuring the successful implementation of blockchain in CSCs. By identifying the most critical roles, stakeholders can direct their efforts and resources toward sustaining the most important roles, which can increase the likelihood of success. For example, firms looking to adopt blockchain in their CSCs can focus on developing information-sharing protocols, fostering collaboration with key stakeholders and implementing end-to-end traceability measures. This involves identifying the types of information to share across the CSC, as well as the frequency and methods of sharing. Saberi et al. (2019) highlight that CSC stakeholders need to identify key information requirements and develop clear guidelines for sharing information. As a result, it is crucial to implement standardised data formats and communication protocols to ensure consistency and interoperability across the CSC (Kayıkcı & Subramanian, 2022).

5.2 | Practical implications

The present study has implications for practitioners and managers. Although research on blockchain adoption in the CSC context is limited, prior studies indicate that digital technologies are crucial for achieving the transition to CSCs by facilitating resource conservation, loop closure and new business opportunities (Gong et al., 2022; Huang et al., 2022; Kayikci et al., 2022). Gaining insights into 12 fundamental roles of blockchain entrepreneurship in fostering the development of CSCs with the base of SLR, theory of change and start-up examples can be valuable for managers seeking to implement blockchain-based strategies effectively. Examples of start-ups drawn from different industries offer a wider range of results for organisations, supply chain professionals and managers. In addition, since the research is theory-based, it has a solid foundation for managers. Moreover, identifying the causal interrelationships between these roles of blockchain entrepreneurship in the CSC transition and validating them through case study analysis and expert opinions can help practitioners comprehend the essential drivers for promoting CSCs and addressing sustainability challenges. Overall, the study findings suggest that CSC stakeholders can leverage blockchain technology to increase CSC integration, enhance transparency and traceability and enable the development of closed-loop systems. The integration of different stakeholders is a crucial factor for the success of CSCs. Blockchain technology can enable the seamless integration of CSC stakeholders by providing a shared and immutable ledger that can be accessed by all parties. This can enable better communication and collaboration, which are essential for the effective functioning of CSCs (Kayikci et al., 2022). Moreover, the transparency and traceability of supply chains are crucial for ensuring the origin and authenticity of products (Kouhizadeh et al., 2021; Rejeb et al., 2019). Blockchain can enhance transparency by providing a tamper-proof and auditable record of all transactions. By accessing the data stored on blockchain concerning the raw materials and methods used in the manufacturing process, end customers can improve their purchasing decisions with better information. The transparency of blockchain can also provide an opportunity for firms to evaluate and compare the state of their CSC. Therefore, firms can use blockchain to design a circular business model that includes self-regulation, increased transparency and better governance, which can mitigate risks associated with various sensitive social issues in supply chains, such as child labour, worker exploitation and environmental issues (Upadhyay et al., 2021).

This study employs an MCDM approach to prioritise the roles of blockchain entrepreneurship in CSCs. This methodological approach offers a means for organisations, supply chain professionals and managers in various industrial contexts to assess the roles of blockchain in supporting CSC operations. Managers and practitioners now have the means to evaluate and gain an understanding of how to transition to CSC through blockchain technology. At a fundamental level, the MCDM approach creates a structured environment for decision-making, which is particularly valuable when dealing with complex and multifaceted problems involving multiple criteria. By leveraging MCDM, practitioners can systematically analyse and prioritise the differing roles of blockchain, aligning them more closely with organisational goals and industry-specific requirements. Similarly, managers and practitioners are now equipped to evaluate and understand the transitioning dynamics to CSCs through the lens of blockchain technology. However, the applicability of MCDM extends beyond mere comprehension. It also assists in creating a strategic roadmap for blockchain integration within the CSC framework. By dissecting each role into understandable and actionable segments, this study guides the strategic planning and operational execution phases, paving the way for smoother technology adoption and more effective transitions. Moreover, the study's findings empower managers to assess the trade-offs between various blockchain roles critically. Given that resources are often limited, understanding these trade-offs can help decision-makers prioritise investments, whether in technological infrastructure, skill development or process redesigning.

It is important to note that the roles of blockchain entrepreneurship in CSC may undergo changes and developments over time. As such, there is a need to evaluate the issue of blockchain entrepreneurship roles for CSC transition in cause-effect categorisation for managers. At this stage, it is a time–saving feature to know which roles effect and which roles cause. Prioritising the most critical roles through ranking allows managers to focus on a few key areas and allocate their resources and investments accordingly. Additionally, ranking the roles provides justification for the selection and implementation of blockchain technology in CSCs. With the 12 fundamental roles defined in this study, this study can be seen as a framework for managers. As a result of the categorisation of the roles defined in this study within the scope of DEMATEL, we can see that the cause group (Providing end-to-end traceability, Alleviating financial problems, Strengthening the competitive advantage of CE business models, Information and knowledge sharing, Supporting clean energy products, Improving process efficiency) has effects on the effect group (Supporting CE practices, Supporting the development of industrial symbiosis, Supporting waste management, Strengthening collaboration and coordination, Supporting product deletion strategies, Supporting trading activities). Given the numerous benefits brought by blockchain in the CSC context, managers should conduct a thorough analysis of their circular processes and identify areas where the technology can provide the most value. Furthermore, there is a need for collaboration with other stakeholders in the CSC to jointly implement blockchain technology. This can help increase the effectiveness of the technology by promoting a transparent, shared platform for information sharing and collaboration. When implementing blockchain in CSC, managers should prioritise data security and privacy. For example, this can be achieved by selecting a suitable blockchain platform that aligns with the security requirement of the firm, as well as employing proper data encryption and access controls to protect sensitive information and streamline resource-sharing processes (Rejeb, Keogh, et al., 2021). The embrace of blockchain entrepreneurship in CSC necessitates the development of new capabilities and working mechanisms. Thus, managers should invest in training and education for their employees to make sure that the workforce has the proper skills and knowledge to operate blockchain effectively in CSC operations.

Finally, firms should regularly evaluate the performance of their blockchain-enabled CSC operations and adjust their strategies accordingly. For example, this can be done by identifying and overcoming any issues or inefficiencies that may arise, as well as continually exploring new ways to optimise CSC processes using blockchain technology.

5.3 | Policy implications

Based on the results of this research, the policy implications are as follows. Policymakers can draw on the findings to design policies and regulations that support the adoption of blockchain in the development of CSCs. For example, policies can be implemented to encourage information sharing and collaboration between CSC stakeholders (Kayikci et al., 2022). Regulations can also be put in place to support the development of blockchain start-ups and offer funding for research and development in the CSC area. Policies can include funding schemes, tax incentives (Khan, Ponce, et al., 2021) and regulatory sandboxes, among others. These policies can help to create a favourable environment for blockchain start-ups to thrive and grow, which can, in turn, accelerate the adoption of blockchain in CSCs. For example, funding schemes can provide financial support to blockchain start-ups to develop and test their solutions in real-world settings. Consequently, this can help to overcome some of the barriers to entry that start-ups and SMEs often encounter, such as prohibitive development costs and constrained budgets. Moreover, tax incentives can be used to support the development of blockchain-enabled CSC systems by reducing the financial burden of regulatory compliance and other costs. In this regard, tax credits can be offered for investments in blockchain technologies or for the development of blockchain solutions that promote circularity in supply chains (Kouhizadeh et al., 2020). As supporting information sharing and collaboration constitute one of the essential roles of blockchain entrepreneurship in CSCs, policymakers and governments may be interested in devising policies that promote information sharing and collaboration among CSC stakeholders, such as mandating the use of common data formats and standards, encouraging and rewarding the sharing of information and allocating funds for collaborative research and development initiative in the CSC domain. Finally, policymakers have the opportunity to launch regulations that demand complete traceability within the CSC. This can lead to increased product transparency and accountability. These regulations can include mandating the adoption of blockchain to track and authenticate the origin and flow of products across the CSC. The development of certification programmes that recognise firms that use blockchain to support CSC operations can also create equal opportunities for adopters of blockchain and provide consumers with a way to identify CSC actors committed to transparency, circularity and sustainability (Rejeb, Zailani, et al., 2022).

6 | CONCLUSION

Stakeholders may use blockchain-based CSC to better administer business decision-making activities, improve income, decrease time and expenses and assure knowledge integration. Blockchain start-ups perform a significant function in easing the shift from a linear to a CE and in fostering the growth of CSCs. The focus of this paper is to evaluate circular blockchain start-ups to investigate the role of blockchain entrepreneurship in the shift to CSC. The scientific value added of this research paper is threefold which are: firstly, the impact of blockchain entrepreneurship on CSC is investigated; secondly, fundamental roles of blockchain entrepreneurship are identified from the literature and empirically validated by experts; finally, fundamental roles are recognised, and their inter-relationships are assessed. To determine the roles of blockchain, a comprehensive literature study is conducted. After determining the roles for validation via assessments of start-up use case scenarios, the second phase is to undertake QCA. Ultimately, Fuzzy-DEMATEL is employed to examine the causal linkages between the roles. According to the findings, blockchain plays 12 roles in easing the shift from a linear to a CE while accelerating the development of CSCs. According to the findings, 'information and knowledge sharing' is the most influential function among the others. Furthermore, 'strengthening collaboration and coordination' is the most causative role. The next causal function is 'supporting CE practices'. This study has covered the roles of blockchain quite extensively.

Although the current study carries notable insights, several inherent constraints warrant mention. First, the principal methodological approach, namely, QCA and Fuzzy-DEMATEL, significantly emphasises expert perspectives and discretionary evaluations. Such a heavy reliance on subjective viewpoints could potentially imbue the analysis with undue biases and constrictions, thereby engendering doubts about the methodological rigour of the research. Furthermore, the sample size and representativeness of the consulted experts, which may be circumscribed, can jeopardise the extrapolation of the results to a larger demographic and potentially narrow the global relevance and applicability of the study's results. Despite the innovative amalgamation of QCA and Fuzzy-DEMATEL, this research may not fully encapsulate the dynamism and intricacies of the CSC environment. This milieu involves a plethora of diverse stakeholders and an expansive array of determinants, all of which hold the potential to shape the success trajectory of blockchain entrepreneurship. Therefore, the employed methodologies may prove insufficient in capturing the vast complexity of this context. Moreover, the applications of these methods may be found wanting in their ability to enable a profound understanding of the specific mechanisms and processes that underpin how blockchain technology can expedite the transition to CSCs. As a result, this raises the necessity for integrating additional methods and investigative strategies to ensure a more nuanced comprehension of blockchain technology's role in CSCs. The lack of a more holistic understanding might inadvertently limit the potential for innovation and systemic change towards more sustainable business practices. Finally, the dynamic nature of CSCs and blockchain technology suggests that a cross-sectional perspective may fail to capture essential temporal variations and the evolution of the connection between these concepts. Consequently, the interpretations of the study's findings should be approached with prudence, given the potential constraints imposed by the chosen methodological framework.

In further research, more start-ups can be considered. Methodologically, the hierarchical cause–effect relationship between roles can be examined by applying total interpretive structural modelling. This could help to provide a more nuanced understanding of how these roles interact and influence each other, which can inform more targeted interventions to support the adoption of blockchain technology in CSCs. Moreover, the transition process can be analysed by including CE models. Future researchers can apply other methods, such as system dynamics modelling and social network analysis, to further investigate the dynamics of blockchain entrepreneurship in CSCs. Given that the focus is on the roles of blockchain in the transition to CSCs without considering the broader context of sustainability and environmental issues, future studies can expand the scope of the analysis to consider other sustainability-related factors and examine their interrelationships with the roles studied in this work. In addition, researchers can carry out a comparative analysis of different blockchain-based solutions in circular solutions to determine the most efficient and effective approach to implementing these solutions. This can involve exploring case studies of successful implementations, as well as conducting controlled experiments to test the different approaches and identify best practices. The potential ethical and social implications of blockchain adoption in CSCs, such as power dynamics, data ownership and privacy issues, can be examined. In this regard, researchers can conduct surveys or focus groups with CSC stakeholders to understand their perspectives and concerns, as well as create frameworks for ethical and responsible decision-making in the deployment of blockchain. This study overlooks the potential synergies between blockchain technology and other cutting-edge technologies, such as big data analytics, artificial intelligence and additive manufacturing, in accelerating the transition towards CSCs. Thus, future studies can develop integrated systems that leverage the strengths of these different technologies to provide more transparent, efficient and sustainable supply chain solutions. Finally, it is recommended that researchers perform longitudinal studies to evaluate the long-term effect of blockchain-based solutions on CSCs, including factors such as cost-effectiveness, adoption rates and environmental impact. For instance, this can involve assessing the implementation and outcomes of blockchain systems over time and carrying out regular evaluations to discover areas for improvement and optimisation.

AUTHOR CONTRIBUTIONS

All authors contributed properly to the work. All listed authors are eligible for authorship according to the specified criteria.

ACKNOWLEDGEMENTS

The first author gratefully acknowledges the support provided by Scientific and Technological Research Council of Turkey under the grant number 1929B021801076 for this research.

CONFLICT OF INTEREST STATEMENT

There is no conflict of interest to be declared.

ORCID

Yasanur Kayikci https://orcid.org/0000-0003-2406-3164
Abderahman Rejeb https://orcid.org/0000-0002-2817-5377

REFERENCES

Adel, H. M., & Younis, R. A. A. (2021). Interplay among blockchain technology adoption strategy, e-supply chain management diffusion, entrepreneurial orientation and human resources information system in banking. *International Journal of Emerging Markets*. https://doi.org/10.1108/ijoem-02-2021-0165

Ahluwalia, S., Mahto, R. V., & Guerrero, M. (2020). Blockchain technology and startup financing: A transaction cost economics perspective. *Technological Forecasting and Social Change*, *151*, 119854. https://doi.org/10.1016/j.techfore.2019.119854

Ajwani-Ramchandani, R., Figueira, S., Torres de Oliveira, R., Jha, S., Ramchandani, A., & Schuricht, L. (2021). Towards a circular economy for packaging waste by using new technologies: The case of large multinationals in emerging economies. *Journal of Cleaner Production*, *281*, 125139. https://doi.org/10.1016/j.jclepro.2020.125139

Alnajem, M., Mostafa, M. M., & ElMelegy, A. R. (2020). Mapping the first decade of circular economy research: a bibliometric network analysis. *Journal of Industrial and Production Engineering*, *38*(1), 29–50. https://doi.org/10.1080/21681015.2020.1838632

Annie, E. (2004). *Theory of Change: A Practical Tool For Action, Results and Learning* (pp. 10–11). Casey Foundation.

Asante, R., Agyemang, M., Faibil, D., & Osei-Asibey, D. (2022). Roles and actions of managers in circular supply chain implementation: A resource orchestration perspective. *Sustainable Production and Consumption*, *30*, 64–76. https://doi.org/10.1016/j.spc.2021.11.028

Ashley, M. J., & Johnson, M. S. (2018). Establishing a secure, transparent, and autonomous blockchain of custody for renewable energy credits and carbon credits. *IEEE Engineering Management Review*, *46*(4), 100–102. https://doi.org/10.1109/EMR.2018.2874967

Bai, C., & Sarkis, J. (2020). A supply chain transparency and sustainability technology appraisal model for blockchain technology. *International Journal of Production Research*, *58*(7), 2142–2162. https://doi.org/10.1080/00207543.2019.1708989

BanQu. (2021). *Optimizing the Circular Economy: Coca-Cola and BanQu*. BanQu, available at:. https://banqu.co/use-cases/optimizing-the-circular-economy-coca-cola-and-banqu/ accessed 29 September 2022

Batista, L., Gong, Y., Pereira, S., Jia, F., & Bittar, A. (2019). Circular supply chains in emerging economies—A comparative study of packaging recovery ecosystems in China and Brazil. *International Journal of Production Research*, *57*(23), 7248–7268. https://doi.org/10.1080/00207543.2018.1558295

Beamon, B. M. (1999). Designing the green supply chain. *Logistics Information Management*, *12*(4), 332–342. https://doi.org/10.1108/09576059910284159

Belaud, J.-P., Adoue, C., Vialle, C., Chorro, A., & Sablayrolles, C. (2019). A circular economy and industrial ecology toolbox for developing an eco-industrial park: perspectives from French policy. *Clean Technologies and Environmental Policy*, *21*(5), 967–985. https://doi.org/10.1007/s10098-019-01677-1

Benstead, A. V., Mwesiumo, D., Moradlou, H., & Boffelli, A. (2022). Entering the world behind the clothes that we wear: Practical applications of blockchain technology. *Production Planning & Control*, 1–18. https://doi.org/10.1080/09537287.2022.2063173

Böckel, A., Nuzum, A. K., & Weissbrod, I. (2021). Blockchain for the circular economy: Analysis of the research-practice gap. *Sustainable Production* *and Consumption*, *25*, 525–539. https://doi.org/10.1016/j.spc.2020.12.006

Böhmecke-Schwafert, M., Wehinger, M., & Teigland, R. (2022). Blockchain for the circular economy: Theorizing blockchain's role in the transition to a circular economy through an empirical investigation. *Business Strategy and the Environment.*, *31*(8), 3786–3801. https://doi.org/10.1002/bse.3032

Brest, P. (2010), The power of theories of change, available at: https://sc4ccm.jsi.com/wp-content/uploads/2016/07/The-Power-Of-Theories-Of-Change.pdf (accessed 20 August 2022).

Brignac, K. (2021). RemediChain, BurstIQ Partner to Incentivize Medication Donations Through App. Www.businesswire.com, 27 May, available at: https://www.businesswire.com/news/home/20210527005804/en/RemediChain-BurstIQ-Partner-to-Incentivize-Medication-Donations-Through-App (accessed 7 September 2022).

Briones, N. (2020). Current State of Drug Recycling Programs in the United States Current State of Drug Recycling Programs in the United States, available at: https://chicagounbound.uchicago.edu/cgi/viewcontent.cgi?article=1121&context=international_immersion_program_papers (accessed 7 September 2022).

Catalini, C., & Gans, J. S. (2020). Some simple economics of the blockchain. *Communications of the ACM*, *63*(7), 80–90. https://doi.org/10.1145/3359552

Centobelli, P., Cerchione, R., Del Vecchio, P., Oropallo, E., & Secundo, G. (2022). Blockchain technology for bridging trust, traceability and transparency in circular supply chain. *Information & Management*, *59*(7), 103508. https://doi.org/10.1016/j.im.2021.103508

Chakrabarty, A., & Nandi, S. (2021). Electronic waste vulnerability: Circular economy as a strategic solution. *Clean Technologies and Environmental Policy*, *23*(2), 429–443. https://doi.org/10.1007/s10098-020-01976-y

Chaouni Benabdellah, A., Zekhnini, K., Cherrafi, A., Garza-Reyes, J. A., Kumar, A., & El Baz, J. (2023). Blockchain technology for viable circular digital supplychains: An integrated approach for evaluating the implementation barriers. *Benchmarking: An International Journal*. https://doi.org/10.1108/BIJ-04-2022-0240

Chari, A., Niedenzu, D., Despeisse, M., Machado, C. G., Azevedo, J. D., Boavida-Dias, R., & Johansson, B. (2022). Dynamic capabilities for circular manufacturing supply chains—Exploring the role of Industry 4.0 and resilience. *Business Strategy and the Environment*, *31*(5) Article 5, 2500–2517. https://doi.org/10.1002/bse.3040

Chaudhuri, A., Bhatia, M. S., Kayikci, Y., Fernandes, K. J., & Fosso-Wamba, S. (2021). Improving social sustainability and reducing supply chain risks through blockchain implementation: Role of outcome and behavioural mechanisms. *Annals of Operations Research*. https://doi.org/10.1007/s10479-021-04307-6

Chaudhuri, A., Bhatia, M. S., Subramanian, N., Kayikci, Y., & Dora, M. (2022). Socio-technical capabilities for blockchain implementation by service providers: Multiple case study of projects with transaction time reduction and quality improvement objectives. *Production Planning & Control*, 1–14. https://doi.org/10.1080/09537287.2022.2128865

ChemChain. (2020). *ChemChain|Track chemicals along the value chain*. Chemcha.in, available at:. https://chemcha.in/ accessed 1 October 2022

Cheng, H. K., Hu, D., Puschmann, T., & Zhao, J. L. (2021). The landscape of blockchain research: Impacts and opportunities. *Information Systems and e-Business Management*, *19*(3), 749–755. https://doi.org/10.1007/s10257-021-00544-1

Chidepatil, A., Bindra, P., Kulkarni, D., Qazi, M., Kshirsagar, M., & Sankaran, K. (2021). From trash to cash: How blockchain and multi-sensor-driven artificial intelligence can transform circular economy of plastic waste? *Administrative Sciences*, *10*(2), 23. https://doi.org/10.3390/admsci10020023

Chiu, J., & Koeppl, T. (2019). Incentive compatibility on the blockchain. In W. Trockel (Ed.), Social Design. *Studies in Economic Design*. Springer, Cham. https://doi.org/10.1007/978-3-319-93809-7_20

Choudhary, D., Qaiser, F. H., Choudhary, A., & Fernandes, K. (2022). A model for managing returns in a circular economy context: A case study from the Indian electronics industry. *International Journal of Production Economics*, *249*, 108505. https://doi.org/10.1016/j.ijpe.2022.108505

Christensen Institute. (2016). *Disruptive Innovations*. Christensen Institute, available at:. https://www.christenseninstitute.org/disruptive-innovations/ accessed 2 October 2022

Circularise. (2022). "ISCC and Circularise pilot blockchain technology. www.circularise.com, available at: https://www.circularise.com/press-release/iscc-and-circularise-pilot-blockchain-technology (accessed 3 October 2022).

Connell, J. P., & Kubisch, A. C. (1998). Applying a theory of change approach to the evaluation of comprehensive community initiatives: progress, prospects, and problems. *New Approaches to Evaluating Community Initiatives*, *2*(15–44), 1–16.

Cordis. (2020). Blockchain Platform to Track Chemicals along the Value Chain. www.europa.eu, available at: https://cordis.europa.eu/project/id/875783 (accessed 7 September 2022).

de Abreu, M. C. S., & Ceglia, D. (2018). On the implementation of a circular economy: The role of institutional capacity-building through industrial symbiosis. *Resources, Conservation and Recycling*, *138*, 99–109. https://doi.org/10.1016/j.resconrec.2018.07.001

de Giovanni, P. (2022). Leveraging the circular economy with a closed-loop supply chain and a reverse omnichannel using blockchain technology and incentives. *International Journal of Operations & Production Management*, *42*(7), 959–994. https://doi.org/10.1108/IJOPM-07-2021-0445

Deutz, P., Baxter, H., Gibbs, D., Mayes, W. M., & Gomes, H. I. (2017). Resource recovery and remediation of highly alkaline residues: A political-industrial ecology approach to building a circular economy. *Geoforum*, *85*, 336–344. https://doi.org/10.1016/j.geoforum.2017.03.021

di Maria, E., de Marchi, V., & Galeazzo, A. (2022). Industry 4.0 technologies and circular economy: The mediating role of supply chain integration. *Business Strategy and the Environment*, *31*(2), 619–632. https://doi.org/10.1002/bse.2940

Domenech, T., Bleischwitz, R., Doranova, A., Panayotopoulos, D., & Roman, L. (2019). Mapping Industrial Symbiosis Development in Europe_ typologies of networks, characteristics, performance and contribution to the Circular Economy. *Resources, Conservation and Recycling*, *141*, 76–98. https://doi.org/10.1016/j.resconrec.2018.09.016

Du, L., Yu, L. & Cheng, R. (2010). The construction research on Rapid-Response Eco-Supply Chain of the textile industry based on the circular economy. *2010 International Conference on E-Health Networking Digital Ecosystems and Technologies (EDT)*, 1, 248–251. 10.1109/EDT.2010.5496593

Du, P., Yang, X., Xu, L., Tan, Y., & Li, H. (2020). Green design strategies of competing manufacturers in a sustainable supply chain. *Journal of Cleaner Production*, *265*, 121853. https://doi.org/10.1016/j.jclepro.2020.121853

Dutta, P., Choi, T.-M., Somani, S., & Butala, R. (2020). Blockchain technology in supply chain operations: Applications, challenges and research opportunities. *Transportation Research. Part E, Logistics and Transportation Review*, *142*(1), 102067. https://doi.org/10.1016/j.tre.2020.102067

el Bilali, H. (2019). The multi-level perspective in research on sustainability transitions in agriculture and food systems: A systematic review. *Agriculture*, *9*(4), 74. https://doi.org/10.3390/agriculture9040074

Elghaish, F., Hosseini, M. R., Kocaturk, T., Arashpour, M., & Bararzadeh Ledari, M. (2023). Digitalised circular construction supply chain: An integrated BIM-Blockchain solution. *Automation in Construction*, *148*, 104746. https://doi.org/10.1016/j.autcon.2023.104746

Esmaeilian, B., Sarkis, J., Lewis, K., & Behdad, S. (2020). Blockchain for the future of sustainable supply chain management in Industry 4.0.

Resources, Conservation and Recycling, 163, 105064. https://doi.org/10.1016/j.resconrec.2020.105064
EverLedger. (2021). *The Everledger Platform*. Everledger, available at:. https://everledger.io/ accessed 2 October 2022
Fang, C., Ma, X., Zhang, J., & Zhu, X. (2021). Personality information sharing in supply chain systems for innovative products in the circular economy era. *International Journal of Production Research*, *59*(19), 5992–6001. https://doi.org/10.1080/00207543.2020.1798032
Farooque, M., Zhang, A., Thürer, M., Qu, T., & Huisingh, D. (2019). Circular supply chain management: A definition and structured literature review. *Journal of Cleaner Production*, *228*, 882–900. https://doi.org/10.1016/j.jclepro.2019.04.303
Fehrer, J. A., & Wieland, H. (2021). A systemic logic for circular business models. *Journal of Business Research*, *125*, 609–620. https://doi.org/10.1016/j.jbusres.2020.02.010
Fleischmann, M., Bloemhof-Ruwaard, J. M., Dekker, R., van der Laan, E., van Nunen, J. A. E. E., & van Wassenhove, L. N. (1997). Quantitative models for reverse logistics: A review. *European Journal of Operational Research*, *103*(1), 1–17. https://doi.org/10.1016/S0377-2217(97)00230-0
Fontela, E., & Gabus, A. (1976). *The DEMATEL Observer*. Battelle Geneva Research Center.
Frizzo-Barker, J., Chow-White, P. A., Adams, P. R., Mentanko, J., Ha, D., & Green, S. (2019). Blockchain as a disruptive technology for business: A systematic review. *International Journal of Information Management*, *51*(102029), 102029. https://doi.org/10.1016/j.ijinfomgt.2019.10.014
Gebhardt, M., Kopyto, M., Birkel, H., & Hartmann, E. (2021). Industry 4.0 technologies as enablers of collaboration in circular supply chains: A systematic literature review. *International Journal of Production Research*, *60*(23), 6967–6995. https://doi.org/10.1080/00207543.2021.1999521
Geels, F. W. (2019). Socio-technical transitions to sustainability: A review of criticisms and elaborations of the Multi-Level Perspective. *Current Opinion in Environmental Sustainability*, *39*, 187–201. https://doi.org/10.1016/j.cosust.2019.06.009
Geissdoerfer, M., Morioka, S. N., de Carvalho, M. M., & Evans, S. (2018). Business models and supply chains for the circular economy. *Journal of Cleaner Production*, *190*, 712–721. https://doi.org/10.1016/j.jclepro.2018.04.159
Geissdoerfer, M., Savaget, P., Bocken, N. M. P., & Hultink, E. J. (2017). The circular economy—A new sustainability paradigm? *Journal of Cleaner Production*, *143*(143), 757–768. https://doi.org/10.1016/j.jclepro.2016.12.048
Genovese, A., Acquaye, A. A., Figueroa, A., & Koh, S. C. L. (2017). Sustainable supply chain management and the transition towards a circular economy: Evidence and some applications. *Omega*, *66*, 344–357. https://doi.org/10.1016/j.omega.2015.05.015
Genus, A., & Coles, A.-M. (2008). Rethinking the multi-level perspective of technological transitions. *Research Policy*, *37*(9), 1436–1445. https://doi.org/10.1016/j.respol.2008.05.006
Ghode, D. J., Yadav, V., Jain, R., & Soni, G. (2021). Lassoing the bullwhip effect by applying blockchain to supply chains. *Journal of Global Operations and Strategic Sourcing*, *15*(1), 96–114. https://doi.org/10.1108/JGOSS-06-2021-0045
Gong, Y., Wang, Y., Frei, R., Wang, B., & Zhao, C. (2022). Blockchain application in circular marine plastic debris management. *Industrial Marketing Management*, *102*, 164–176. https://doi.org/10.1016/j.indmarman.2022.01.010
González-Sánchez, R., Settembre-Blundo, D., Ferrari, A. M., & García-Muiña, F. E. (2020). Main dimensions in the building of the circular supply chain: A literature review. *Sustainability*, *12*(6), 2459. https://doi.org/10.3390/su12062459
Gotschol, A., de Giovanni, P., & Esposito Vinzi, V. (2014). Is environmental management an economically sustainable business? *Journal of Environmental Management*, *144*, 73–82. https://doi.org/10.1016/j.jenvman.2014.05.001
Grafström, J., & Aasma, S. (2021). Breaking circular economy barriers. *Journal of Cleaner Production*, *292*, 126002. https://doi.org/10.1016/j.jclepro.2021.126002
Gunasekara, H. G., Sridarran, P., & Rajaratnam, D. (2022). Effective use of blockchain technology for facilities management procurement process. *Journal of Facilities Management*, *20*(3), 452–468. https://doi.org/10.1108/JFM-10-2020-0077
Hackius, N., & Petersen, M. (2020). Translating high hopes into tangible benefits: How incumbents in supply chain and logistics approach blockchain. *IEEE Access*, *8*, 34993–35003. https://doi.org/10.1109/ACCESS.2020.2974622
Huang, L., Zhen, L., Wang, J., & Zhang, X. (2022). Blockchain implementation for circular supply chain management: Evaluating critical success factors. *Industrial Marketing Management*, *102*, 451–464. https://doi.org/10.1016/j.indmarman.2022.02.009
Intrac. (2017), Qualitative Comparative Analysis (QCA), available at: https://www.intrac.org/wpcms/wp-content/uploads/2017/01/Qualitative-comparative-analysis.pdf (accessed 10 September 2022).
Kamal, M. M., Mamat, R., Mangla, S. K., Kumar, P., Despoudi, S., Dora, M., & Tjahjono, B. (2022). Immediate return in circular economy: Business to consumer product return information sharing framework to support sustainable manufacturing in small and medium enterprises. *Journal of Business Research*, *151*, 379–396. https://doi.org/10.1016/j.jbusres.2022.06.021
Katsikouli, P., Wilde, A. S., Dragoni, N., & Høgh-Jensen, H. (2020). On the benefits and challenges of blockchains for managing food supply chains. *Journal of the Science of Food and Agriculture*, *101*(6), 2175–2181. https://doi.org/10.1002/jsfa.10883
Kayikci, Y., Durak Usar, D., & Aylak, B. L. (2021). Using blockchain technology to drive operational excellence in perishable food supply chains during outbreaks. *The International Journal of Logistics Management*, *33*(3), 836–876. https://doi.org/10.1108/IJLM-01-2021-0027
Kayikci, Y., Gozacan-Chase, N., Rejeb, A., & Mathiyazhagan, K. (2022). Critical success factors for implementing blockchain-based circular supply chain. *Business Strategy and the Environment.*, *31*, 3595–3615. https://doi.org/10.1002/bse.3110
Kayikci, Y., Kazancoglu, Y., Lafci, C., & Gozacan, N. (2021). Exploring barriers to smart and sustainable circular economy: The case of an automotive eco-cluster. *Journal of Cleaner Production*, *314*, 127920. https://doi.org/10.1016/j.jclepro.2021.127920
Kayikci, Y., Subramanian, N., Dora, M., & Bhatia, M. S. (2020). Food supply chain in the era of Industry 4.0: blockchain technology implementation opportunities and impediments from the perspective of people, process, performance, and technology. *Production Planning & Control*, *32*(2–3), 301–321. https://doi.org/10.1080/09537287.2020.1810757
Kayıkcı, Y., & Subramanian, N. (2022). Blockchain interoperability issues in supply chain: Exploration of mass adoption procedures. In A. Emrouznejad & V. Charles (eds.), *Big Data and Blockchain for Service Operations Management. Studies in Big Data* (pp. 309–328). https://doi.org/10.1007/978-3-030-87304-2_13
Kazancoglu, I., Kazancoglu, Y., Yarimoglu, E., & Kahraman, A. (2020). A conceptual framework for barriers of circular supply chains for sustainability in the textile industry. *Sustainable Development*, *28*(5), 1477–1492. https://doi.org/10.1002/sd.2100
Kazancoglu, Y., Ozkan-Ozen, Y. D., Sagnak, M., Kazancoglu, I., & Dora, M. (2021). Framework for a sustainable supply chain to overcome risks in transition to a circular economy through Industry 4.0. *Production Planning & Control*, 1–16. https://doi.org/10.1080/09537287.2021.1980910
Khadke, S., Gupta, P., Rachakunta, S., Mahata, C., Dawn, S., Sharma, M., Verma, D., Pradhan, A., Krishna, A. M. S., Ramakrishna, S., Chakrabortty, S., Saianand, G., Sonar, P., Biring, S., Dash, J. K., & Dalapati, G. K. (2021). Efficient plastic recycling and remolding circular

economy using the technology of trust–blockchain. *Sustainability*, *13*(16), 9142. https://doi.org/10.3390/su13169142

Khan, A. A., & Abonyi, J. (2022). Information sharing in supply chains—Interoperability in an era of circular economy. *Cleaner Logistics and Supply Chain*, *5*, 100074. https://doi.org/10.1016/j.clscn.2022.100074

Khan, S. A. R., Godil, D. I., Jabbour, C. J. C., Shujaat, S., Razzaq, A., & Yu, Z. (2021). Green data analytics, blockchain technology for sustainable development, and sustainable supply chain practices: Evidence from small and medium enterprises. *Annals of Operations Research*. https://doi.org/10.1007/s10479-021-04275-x

Khan, S. A. R., Ponce, P., Thomas, G., Yu, Z., Al-Ahmadi, M. S., & Tanveer, M. (2021). Digital Technologies, circular economy practices and environmental policies in the era of COVID-19. *Sustainability*, *13*(22), 22. https://doi.org/10.3390/su132212790

Khan, S. A. R., Razzaq, A., Yu, Z., & Miller, S. (2021). Industry 4.0 and circular economy practices: A new era business strategies for environmental sustainability. *Business Strategy and the Environment*, *30*(8), 4001–4014. https://doi.org/10.1002/bse.2853

Khanna, M., Gusmerotti, N. M., & Frey, M. (2022). The relevance of the circular economy for climate change: An exploration through the theory of change approach. *Sustainability*, *14*(7), 3991. https://doi.org/10.3390/su14073991

Kirchherr, J., Reike, D., & Hekkert, M. (2017). Conceptualizing the circular economy: An analysis of 114 definitions. *Resources, Conservation and Recycling*, *127*, 221–232. https://doi.org/10.1016/j.resconrec.2017.09.005

Korhonen, J., Honkasalo, A., & Seppälä, J. (2018). Circular economy: The concept and its limitations. *Ecological Economics*, *143*(1), 37–46. https://doi.org/10.1016/j.ecolecon.2017.06.041

Kouhizadeh, M., Saberi, S., & Sarkis, J. (2021). Blockchain technology and the sustainable supply chain: Theoretically exploring adoption barriers. *International Journal of Production Economics*, *231*, 107831. https://doi.org/10.1016/j.ijpe.2020.107831

Kouhizadeh, M., & Sarkis, J. (2018). Blockchain practices, potentials, and perspectives in greening supply chains. *Sustainability*, *10*(10), 3652. https://doi.org/10.3390/su10103652

Kouhizadeh, M., Sarkis, J., & Zhu, Q. (2019). At the nexus of blockchain technology, the circular economy, and product deletion. *Applied Sciences*, *9*(8), 1712. https://doi.org/10.3390/app9081712

Kouhizadeh, M., Zhu, Q., Alkhuzaim, L., & Sarkis, J. (2022). Blockchain technology and the circular economy: An exploration. *Circular Economy Supply Chains: From Chains to Systems*, 189–213. https://doi.org/10.1108/978-1-83982-544-620221010

Kouhizadeh, M., Zhu, Q., & Sarkis, J. (2020). Blockchain and the circular economy: Potential tensions and critical reflections from practice. *Production Planning and Control*, *31*(11–12), 950. https://doi.org/10.1080/09537287.2019.1695925

Kumar, A., & Rahman, S. (2014). RFID-enabled process reengineering of closed-loop supply chains in the healthcare industry of Singapore. *Journal of Cleaner Production*, *85*, 382–394. https://doi.org/10.1016/j.jclepro.2014.04.037

Kumar Bhardwaj, A., Garg, A., & Gajpal, Y. (2021). Determinants of blockchain technology adoption in supply chains by small and medium enterprises (SMEs) in India. *Mathematical Problems in Engineering*, *2021*, 1–14. https://doi.org/10.1155/2021/5537395

Lahane, S., Kant, R., & Shankar, R. (2020). Circular supply chain management: A state-of-art review and future opportunities. *Journal of Cleaner Production*, *258*, 120859. https://doi.org/10.1016/j.jclepro.2020.120859

Larson, C. (2016). *Disruptive Innovation Theory: 4 Key Concepts|HBS Online*. Business Insights - Blog, 15 November, available at:. https://online.hbs.edu/blog/post/4-keys-to-understanding-clayton-christensens-theory-of-disruptive-innovation accessed 4 November 2022

Laskurain-Iturbe, I., Arana-Landín, G., Landeta-Manzano, B., & Uriarte-Gallastegi, N. (2021). Exploring the influence of industry 4.0 technologies on the circular economy. *Journal of Cleaner Production*, *321*, 128944. https://doi.org/10.1016/j.jclepro.2021.128944

LedgerInsights. (2022). *Blockchain Startup Circularise Partners Neste for Recycled Polymers*. Ledger Insights - Blockchain for Enterprise, 2 June, available at:. https://www.ledgerinsights.com/blockchain-startup-circularise-partners-neste-for-recycled-polymers/ accessed 1 October 2022

Li, C. (2013). An integrated approach to evaluating the production system in closed-loop supply chains. *International Journal of Production Research*, *51*(13), 4045–4069. https://doi.org/10.1080/00207543.2013.774467

Li, J., Yuan, Y., & Wang, F. Y. (2019). A novel GSP auction mechanism for ranking Bitcoin transactions in blockchain mining. *Decision Support Systems*, *124*, 113094. https://doi.org/10.1016/j.dss.2019.113094

Lin, C.-J., & Wu, W.-W. (2008). A causal analytical method for group decision-making under fuzzy environment. *Expert Systems with Applications*, *34*(1), 205–213. https://doi.org/10.1016/j.eswa.2006.08.012

Lohmer, J., & Lasch, R. (2020). Blockchain in operations management and manufacturing: Potential and barriers. *Computers & Industrial Engineering*, *149*, 106789. https://doi.org/10.1016/j.cie.2020.106789

MacArthur, E. (2015), Towards a circular economy: Business rationale for an accelerated transition, available at: https://kidv.nl/media/rapportages/towards_a_circular_economy.pdf?1.2.1 (accessed 2 October 2022).

Mackenzie, M., & Blamey, A. (2005). The practice and the theory. *Evaluation*, *11*(2), 151–168. https://doi.org/10.1177/1356389005055538

Manea, D.-I., Istudor, N., Dinu, V., & Paraschiv, D.-M. (2021). Circular economy and innovative entrepreneurship, prerequisites for social progress. *Journal of Business Economics and Management*, *22*(5), 1342–1359. https://doi.org/10.3846/jbem.2021.15547

Mangla, S. K., Kazançoğlu, Y., Yıldızbaşı, A., Öztürk, C., & Çalık, A. (2022). A conceptual framework for blockchain-based sustainable supply chain and evaluating implementation barriers: A case of the tea supply chain. *Business Strategy and the Environment.*, *31*(8), 3693–3716. https://doi.org/10.1002/bse.3027

Mangla, S. K., Luthra, S., Mishra, N., Singh, A., Rana, N. P., Dora, M., & Dwivedi, Y. (2018). Barriers to effective circular supply chain management in a developing country context. *Production Planning & Control*, *29*(6), 551–569. https://doi.org/10.1080/09537287.2018.1449265

Marchant, N. (2021). This start-up is using blockchain to help smallholder farmers prosper. World Economic Forum, available at: https://www.weforum.org/agenda/2021/05/banqu-financial-inclusion-sustainability/ (accessed 18 August 2022).

Martín Gómez, A. M., Aguayo González, F., & Marcos Bárcena, M. (2018). Smart eco-industrial parks: A circular economy implementation based on industrial metabolism. *Resources, Conservation and Recycling*, *135*, 58–69. https://doi.org/10.1016/j.resconrec.2017.08.007

Mastos, T. D., Nizamis, A., Terzi, S., Gkortzis, D., Papadopoulos, A., Tsagkalidis, N., Ioannidis, D., Votis, K., & Tzovaras, D. (2021). Introducing an application of an industry 4.0 solution for circular supply chain management. *Journal of Cleaner Production*, *300*, 126886. https://doi.org/10.1016/j.jclepro.2021.126886

Meng, W., Tischhauser, E. W., Wang, Q., Wang, Y., & Han, J. (2018). When intrusion detection meets blockchain technology: A review. *IEEE Access*, *6*, 10179–10188. https://doi.org/10.1109/ACCESS.2018.2799854

Mercuri, F., della Corte, G., & Ricci, F. (2021). Blockchain technology and sustainable business models: A case study of Devoleum. *Sustainability*, *13*(10), 5619. https://doi.org/10.3390/su13105619

Min, H., & Kim, I. (2012). Green supply chain research: Past, present, and future. *Logistics Research*, *4*(1–2), 39–47. https://doi.org/10.1007/s12159-012-0071-3

Mishra, S., & Tyagi, A. K. (2019, December). Intrusion detection in Internet of Things (IoTs) based applications using blockchain technology. In *2019 Third International Conference on I-SMAC (IoT in Social, Mobile, Analytics and Cloud)(I-SMAC)* (pp. 123–128). IEEE. https://doi.org/10.1108/JGOSS-07-2020-0044

Mohit, M., Kaur, S., & Singh, M. (2021). Design and implementation of transaction privacy by virtue of ownership and traceability in blockchain based supply chain. *Cluster Computing.*, *25*(3), 2223–2240. https://doi.org/10.1007/s10586-021-03425-x

MonoChain. (2019). Blockchain and the circular economy. Medium, 12 June, available at: https://medium.com/@monochainltd/blockchain-and-the-circular-economy-b9e5eea7368 (accessed 18 August 2022).

Montag, L. (2022). Circular economy and supply chains: Definitions, conceptualizations, and research agenda of the circular supply chain framework. *Circular Economy and Sustainability*, *3*(1), 35–75. https://doi.org/10.1007/s43615-022-00172-y

Morseletto, P. (2020). Targets for a circular economy. *Resources, Conservation and Recycling*, *153*, 104553. https://doi.org/10.1016/j.resconrec.2019.104553

Mouffak, P. S. (2021). *A Qualitative Comparative Analysis of Blockchain-Based P2P Power Trading Platforms—Project Library*. Aalborg University. Projekter.aau.dk, available at:, https://projekter.aau.dk/projekter/en/studentthesis/a-qualitative-comparative-analysis-of-blockchainbased-p2p-power-trading-platforms(55509c1b-def4-4c6e-be23-c98163a639b3).html accessed 18 August 2022

Nakamoto, S. (2008), Bitcoin: A peer-to-peer electronic cash system, Bitcoin.org, available at: https://bitcoin.org/bitcoin.pdf (accessed 12 October 2022).

Nandi, S., Sarkis, J., Hervani, A., & Helms, M. (2020). Do blockchain and circular economy practices improve post COVID-19 supply chains? A resource-based and resource dependence perspective. *Industrial Management & Data Systems*, *121*(2), 333–363. https://doi.org/10.1108/IMDS-09-2020-0560

Nandi, S., Sarkis, J., Hervani, A. A., & Helms, M. M. (2021). Redesigning supply chains using blockchain-enabled circular economy and COVID-19 Experiences. *Sustainable Production and Consumption*, *27*, 10–22. https://doi.org/10.1016/j.spc.2020.10.019

Narayan, R., & Tidström, A. (2020). Tokenizing coopetition in a blockchain for a transition to circular economy. *Journal of Cleaner Production*, *263*, 121437. https://doi.org/10.1016/j.jclepro.2020.121437

Nasir, M. H. A., Genovese, A., Acquaye, A. A., Koh, S. C. L., & Yamoah, F. (2017). Comparing linear and circular supply chains: A case study from the construction industry. *International Journal of Production Economics*, *183*, 443–457. https://doi.org/10.1016/j.ijpe.2016.06.008

Opricovic, S., & Tzeng, G. H. (2003). Defuzzification within a multicriteria decision model. *International Journal of Uncertainty, Fuzziness and Knowledge-Based Systems*, *11*(5), 635–652. https://doi.org/10.1142/S0218488503002387

Pakseresht, A., Ahmadi Kaliji, S., & Xhakollari, V. (2022). How blockchain facilitates the transition toward circular economy in the food chain? *Sustainability*, *14*(18), 11754. https://doi.org/10.3390/su141811754

Paul, T., Islam, N., Mondal, S., & Rakshit, S. (2022). RFID-integrated blockchain-driven circular supply chain management: A system architecture for B2B tea industry. *Industrial Marketing Management*, *101*, 238–257. https://doi.org/10.1016/j.indmarman.2021.12.003

Philipp, R., Prause, G., & Gerlitz, L. (2019). Blockchain and smart contracts for entrepreneurial collaboration in maritime supply chains. *Transport and Telecommunication Journal*, *20*(4), 365–378. https://doi.org/10.2478/ttj-2019-0030

Pizzi, S., Corbo, L., & Caputo, A. (2021). Fintech and SMEs sustainable business models: Reflections and considerations for a circular economy. *Journal of Cleaner Production*, *281*, 125217. https://doi.org/10.1016/j.jclepro.2020.125217

Prause, G., & Boevsky, I. (2019). Smart contracts for smart rural supply chains. *Bulgarian Journal of Agricultural Science*, *25*(3), 454–463.

Rane, S. B., & Narvel, Y. A. M. (2021). Re-designing the business organization using disruptive innovations based on blockchain-IoT integrated architecture for improving agility in future Industry 4.0. *Benchmarking: An International Journal*, *28*(5), 1883–1908. https://doi.org/10.1108/BIJ-12-2018-0445

Regan, A. (2017). *Seminar 5: How to Select Cases and Make Comparisons*. Political and Social Science, 20 February, available at:. https://socialscientificresearch.wordpress.com/2017/02/20/seminar-5-how-to-select-cases-and-make-comparisons/ accessed 18 August 2022

Rejeb, A., Keogh, J. G., Simske, S. J., Stafford, T., & Treiblmaier, H. (2021). Potentials of blockchain technologies for supply chain collaboration: a conceptual framework. *The International Journal of Logistics Management*, *32*(3), 973–994. https://doi.org/10.1108/IJLM-02-2020-0098

Rejeb, A., Keogh, J. G., & Treiblmaier, H. (2019). Leveraging the internet of things and blockchain technology in supply chain management. *Future Internet*, *11*(7), 161. https://doi.org/10.3390/fi11070161

Rejeb, A., Rejeb, K., Simske, S., & Treiblmaier, H. (2021). Blockchain technologies in logistics and supply chain management: A bibliometric review. *Logistics*, *5*(4), 72. https://doi.org/10.3390/logistics5040072

Rejeb, A., Suhaiza, Z., Rejeb, K., Seuring, S., & Treiblmaier, H. (2022). The internet of things and the circular economy: A systematic literature review and research agenda. *Journal of Cleaner Production*, *350*, 131439. https://doi.org/10.1016/j.jclepro.2022.131439

Rejeb, A., Zailani, S., Rejeb, K., Treiblmaier, H., & Keogh, J. G. (2022). Modeling enablers for blockchain adoption in the circular economy. *Sustainable Futures*, *4*, 100095. https://doi.org/10.1016/j.sftr.2022.100095

Rogers, D. S., & Tibben-Lembke, R. (2011). An examination of reverse logistics practices. *Journal of Business Logistics*, *22*(2), 129–148. https://doi.org/10.1002/j.2158-1592.2001.tb00007.x

Romero-Hernández, O., & Romero, S. (2018). Maximizing the value of waste: From waste management to the circular economy. *Thunderbird International Business Review*, *60*(5), 757–764. https://doi.org/10.1002/tie.21968

Rose, C. M., & Stegemann, J. A. (2018). Characterising existing buildings as material banks (E-BAMB) to enable component reuse. In *Proceedings of the Institution of Civil Engineers-Engineering Sustainability* (Vol. 172, No. 3) (pp. 129–140). Thomas Telford Ltd. 10.1680/jensu.17.00074

Rubio, S., Chamorro, A., & Miranda, F. J. (2008). Characteristics of the research on reverse logistics (1995–2005). *International Journal of Production Research*, *46*(4), 1099–1120. https://doi.org/10.1080/00207540600943977

Saberi, S., Kouhizadeh, M., Sarkis, J., & Shen, L. (2019). Blockchain technology and its relationships to sustainable supply chain management. *International Journal of Production Research*, *57*(7), 2117–2135. https://doi.org/10.1080/00207543.2018.1533261

Samadhiya, A., Agrawal, R., Kumar, A., & Garza-Reyes, J. A. (2023). Blockchain technology and circular economy in the environment of total productive maintenance: A natural resource-based view perspective. *Journal of Manufacturing Technology Management*, (ahead-of-print), *34*(2), 293–314. https://doi.org/10.1108/JMTM-08-2022-0299

Schiavone, F., Rivieccio, G., Paolone, F., & Rocca, A. (2021). The macro-level determinants of user entrepreneurship in healthcare: An explorative cross-country analysis. *Management Decision*, *59*(5), 1158–1178. https://doi.org/10.1108/MD-10-2019-1427

Shojaei, A., Ketabi, R., Razkenari, M., Hakim, H., & Wang, J. (2021). Enabling a circular economy in the built environment sector through blockchain technology. *Journal of Cleaner Production*, *294*, 126352. https://doi.org/10.1016/j.jclepro.2021.126352

Srivastava, S., Bhadauria, A., Dhaneshwar, S., & Gupta, S. (2019). Traceability and transparency in supply chain management system of pharmaceutical goods through block chain. *International Journal of Scientific and Technology Research*, *8*(12), 3201–3206.

Srivastava, S. K. (2007). Green supply-chain management: A state-of-the-art literature review. *International Journal of Management Reviews*, *9*(1), 53–80. https://doi.org/10.1111/j.1468-2370.2007.00202.x

Stahel, W. R. (2016). The circular economy. *Nature*, *531*(7595), 435–438. https://doi.org/10.1038/531435a

Stemler, A. R. (2013). The JOBS Act and crowdfunding: Harnessing the power—and money—of the masses. *Business Horizons*, *56*(3), 271–275. https://doi.org/10.1016/j.bushor.2013.01.007

Swan, M. (2015). *BLOCKCHAIN: Blueprint for a New Economy*. O'Reilly Media.

Tan, B. Q., Wang, F., Liu, J., Kang, K., & Costa, F. (2020). A blockchain-based framework for green logistics in supply chains. *Sustainability*, *12*(11), 4656. https://doi.org/10.3390/su12114656

TextileToday. (2020). MonoChain transforming circular fashion via blockchain traceability. Textile News, Apparel News, RMG News, Fashion Trends, 21 October, available at: https://www.textiletoday.com.bd/monochain-transforming-circular-fashion-via-blockchain-traceability/ (accessed 18 August 2022).

Thomé, A. M. T., Scavarda, L. F., & Scavarda, A. J. (2016). Conducting systematic literature review in operations management. *Production Planning & Control*, *27*(5), 408–420. https://doi.org/10.1080/09537287.2015.1129464

Tiwari, D., Miscandlon, J., Tiwari, A., & Jewell, G. W. (2021). A review of circular economy research for electric motors and the role of Industry 4.0 technologies. *Sustainability*, *13*(17), 9668. https://doi.org/10.3390/su13179668

Tomić, T., & Schneider, D. R. (2018). The role of energy from waste in circular economy and closing the loop concept—Energy analysis approach. *Renewable and Sustainable Energy Reviews*, *98*, 268–287. https://doi.org/10.1016/j.rser.2018.09.029

Toto, D. (2021). *Team Portables Solution for Lithium-Ion Battery Recycling Involves Incentivizing Consumers*. Recycling Today, available at:. https://www.recyclingtoday.com/article/everledger-team-portables-lithium-ion-battery-recycling-solution/ accessed 22 August 2022

Treiblmaier, H. (2018). The impact of the blockchain on the supply chain: A theory-based research framework and a call for action. *Supply Chain Management: An International Journal*, *23*(6), 545–559. https://doi.org/10.1108/SCM-01-2018-0029

Tseng, M.-L., Tan, R. R., Chiu, A. S. F., Chien, C.-F., & Kuo, T. C. (2018). Circular economy meets industry 4.0: Can big data drive industrial symbiosis? *Resources, Conservation and Recycling*, *131*, 146–147. https://doi.org/10.1016/j.resconrec.2017.12.028

Upadhyay, A., Mukhuty, S., Kumar, V., & Kazancoglu, Y. (2021). Blockchain technology and the circular economy: Implications for sustainability and social responsibility. *Journal of Cleaner Production*, *293*, 126130. https://doi.org/10.1016/j.jclepro.2021.126130

Varriale, V., Cammarano, A., Michelino, F., & Caputo, M. (2020). The unknown potential of blockchain for sustainable supply chains. *Sustainability*, *12*(22), 9400. https://doi.org/10.3390/su12229400

Varriale, V., Cammarano, A., Michelino, F., & Caputo, M. (2021). New organizational changes with blockchain: A focus on the supply chain. *Journal of Organizational Change Management*, *34*(2), 420–438. https://doi.org/10.1108/JOCM-08-2020-0249

Wang, B., Luo, W., Zhang, A., Tian, Z., & Li, Z. (2020). Blockchain-enabled circular supply chain management: A system architecture for fast fashion. *Computers in Industry*, *123*, 103324. https://doi.org/10.1016/j.compind.2020.103324

Weiss, C. H. (1995). Nothing as practical as good theory: Exploring theory-based evaluation for comprehensive community initiatives for children and families. *New Approaches to Evaluating Community Initiatives: Concepts, Methods, and Contexts*, *1*, 65–92.

Wu, W. W., & Lee, Y. T. (2007). Developing global managers' competencies using the fuzzy DEMATEL method. *Expert Systems with Applications*, *32*(2), 499–507. https://doi.org/10.1016/j.eswa.2005.12.005

Xavier, L. H., Giese, E. C., Ribeiro-Duthie, A. C., & Lins, F. A. F. (2021). Sustainability and the circular economy: A theoretical approach focused on e-waste urban mining. *Resources Policy*, *74*, 101467. https://doi.org/10.1016/j.resourpol.2019.101467

Xu, D. L., Lu, Y., & Li, L. (2021). Embedding blockchain technology into IoT for security: A survey. *IEEE Internet of Things Journal*, *8*(13), 10452–10473. https://doi.org/10.1109/JIOT.2021.3060508

Xu, M., Chen, X., & Kou, G. (2019). A systematic review of blockchain. *Financial Innovation*, *5*(1), 27. https://doi.org/10.1186/s40854-019-0147-z

Yadav, V. S., Singh, A. R., Raut, R. D., & Govindarajan, U. H. (2020). Blockchain technology adoption barriers in the Indian agricultural supply chain: An integrated approach. *Resources, Conservation and Recycling*, *161*, 104877. https://doi.org/10.1016/j.resconrec.2020.104877

Yager, R. R., & Filev, D. P. (1994). *Essentials of fuzzy modeling and control*. John Wiley & Sons Incorporated.

Yu, H., Sun, H., Wu, D., & Kuo, T.-T. (2019). Comparison of smart contract blockchains for healthcare applications. *AMIA Annual Symposium Proceedings*, *2019*, 1266–1275.

Yu, Z., Khan, S. A. R., & Umar, M. (2022). Circular economy practices and industry 4.0 technologies: A strategic move of automobile industry. *Business Strategy and the Environment*, *31*(3), 796–809. https://doi.org/10.1002/bse.2918

Zamfir, A. M., Mocanu, C., & Grigorescu, A. (2017). Circular economy and decision models among European SMEs. *Sustainability*, *9*(9), 1507. https://doi.org/10.3390/su9091507

Zheng, T., Ardolino, M., Bacchetti, A., & Perona, M. (2021). The applications of Industry 4.0 technologies in manufacturing context: A systematic literature review. *International Journal of Production Research*, *59*(6), 1922–1954. https://doi.org/10.1080/00207543.2020.1824085

Zhu, Q., & Kouhizadeh, M. (2019). Blockchain technology, supply chain information, and strategic product deletion management. *IEEE Engineering Management Review*, *47*(1), 36–44. https://doi.org/10.1109/EMR.2019.2898178

Zhu, Q., Kouhizadeh, M., & Sarkis, J. (2021). Formalising product deletion across the supply chain: blockchain technology as a relational governance mechanism. *International Journal of Production Research*, *60*(1), 92–110. https://doi.org/10.1080/00207543.2021.1987552

How to cite this article: Kayikci, Y., Gozacan-Chase, N., & Rejeb, A. (2023). Blockchain entrepreneurship roles for circular supply chain transition. *Business Strategy and the Environment*, 1–26. https://doi.org/10.1002/bse.3489