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Blockchain applications in the agri-food sector: current insights, challenges and research avenues

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Abstract

Purpose – With the growing entrepreneurial enthusiasm surrounding blockchain, there has been a notable surge in academic discussions regarding the business implications of integrating this technology into the agri-food industry. This trend is expected to persist and evolve in the future. Hence, there is a need to organize and consolidate the existing knowledge, discern prevailing trends and articulate a comprehensive roadmap for guiding future research endeavors in this domain.

Design/methodology/approach – We combine bibliometric network analyses with a detailed systematic review of the related management literature published between 2008 and 2022.

Findings – Our results indicate that debate has clustered around the operations management domain, with a dominance of practice-oriented topics. Most of the literature has been published in top-tier journals, with a recent opening toward empirical research and conceptualization efforts. Both signs show that scholars have acknowledged the prominence of the construct and started to theorize about it. Eventually, the analysis provides a conceptual map, unveils the trends emerging in the received studies and yields conclusions that are helpful to scholars engaging with digital tools in traditional industries.

Originality/value – Our approach blends quantitative analysis with a comprehensive and systematic overview, providing a complementary viewpoint on the topic.

Keywords Blockchain, Agri-food, Bibliometrics, Co-citation analysis, keywords co-occurrence

Paper type Literature review

1. Introduction

The modern agri-food supply chain, characterized by its intricate and fragmented structure involving a diverse network of stakeholders across various levels and geographical locations (Mukherjee *et al.*, 2022), poses significant challenges in effectively managing risks associated with regulatory policies and opportunistic actions (Sarpong, 2014). Incidents such as fraud, food scandals and inefficient supply networks have not only diminished consumer confidence in agri-food systems but have also resulted in substantial losses in output and employment, as evidenced in countries like Italy (Rainero and Modarelli, 2021; Rocchi *et al.*, 2020).

In response to these challenges, agri-food companies are adopting tools to enhance coordination, traceability and sustainability along the supply chain. The integration of blockchain technology has emerged as a transformative solution, alleviating industry pressures by providing secure data transactions through decentralized, distributed and immutable ledgers (Nakamoto, 2008). This technology holds the potential to establish robust

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trust mechanisms among network participants, driving innovation and reshaping existing business models and frameworks (Tandon *et al.*, 2021).

As entrepreneurial interest in blockchain grows, academic discourse on the business-related consequences of its adoption in traditional industries is exponentially rising and expected to continue (Zhao *et al.*, 2019). In light of this, our paper contributes to the existing body of literature by conducting a bibliometric analysis and a systematic review of literature published between 2008 and 2022. The aim is to answer the following critical questions: "*What evolutionary path has this domain followed in business-related research? What knowledge framework has been established? What are the current gaps and what is the roadmap for future research?*".

By combining bibliometric network analyses with a detailed systematic review, we categorize past studies into three main conceptual areas: (1) the integration of disruptive technologies for addressing food security and sustainability challenges, encompassing social, environmental and economic benefits; (2) the use of blockchain to enhance food traceability and safety, reducing fraud and improving consumer confidence and (3) the use of blockchain to transform the supply chain through complementary tools. Moreover, we identified the exact theoretical underpinnings that have driven the advancement of this body of knowledge. Our results indicate that knowledge of blockchain technology in the agri-food sector has clustered around the operations management domain, with a dominance of practice-oriented topics. In detail, information and operations and technology management areas constitute the roots of the field, while the operations management area has enabled its diffusion, describing practical issues related to sustainability, traceability and supply chain logistics. Most of the literature has been published in top-tier journals, with a recent opening toward empirical research and conceptualization efforts. Both signs that scholars have recognized the prominence of the construct.

Building upon prior review articles that extensively examined the applications, potentials and challenges of blockchain technology in the agri-food supply chain across various theoretical lenses (Rana *et al.*, 2021; Pandey *et al.*, 2022; Dal Mas *et al.*, 2023), our research contributes by consolidating current knowledge into a comprehensive, theory-driven conceptual framework. By synthesizing existing theoretical perspectives, our study aims to elucidate the underlying mechanisms and dynamics governing blockchain adoption in the agri-food sector. The resulting conceptual map not only enhances our understanding of the complex interplay between technology and organizational contexts but also provides a solid foundation for future research endeavors.

The structure of the paper is as follows. Section 2 delves into the research design, methodologies and sample selection. Section 3 presents our findings, while Section 4 discusses and integrates them into a conceptual map, providing directions for further research. Finally, Section 5 discusses the implications of our findings and concludes the paper.

2. Research design

2.1 Methodologies

To describe the evolution of the business literature on blockchain technology in the agri-food sector and provide insights for future research, we complemented bibliometric tools with a qualitative analysis of published academic studies (Thomas and Tee, 2022). In doing so, we identify the conceptual structures of knowledge domains using mathematical and statistical methods (Donthu *et al.*, 2021) while deepening the understanding of the bibliometric results through an in-depth systematic approach (Thomas and Tee, 2022).

Following common approaches in business research, we focused on two bibliometric techniques, namely *keywords co-occurrence* and *document co-citation analyses*. While the

former identifies the most frequently addressed topics in the literature by mapping the interactions and strength of association between keywords as well as their evolution over time, the latter traces the intellectual roots of a research area through the identification of its core works (Donthu *et al.*, 2021). We conducted the bibliometric analysis with the VOSviewer software (Van Eck and Waltman, 2014), which is a specialized software for building and visualizing bibliometric networks. After rigorously classifying the extant literature through bibliometrics, we leveraged these results as a starting point for a qualitative literature review. As such, we were able to analytically connect the documents (Thomas and Tee, 2022) and take a comprehensive view of the content, ultimately identifying a potential pathway for the advancement of the field (Jones and Gatrell, 2014).

2.2 Sample selection and description

In this work, we rely on a collection of bibliographic data from the Web of Science (WoS) database managed by Clarivate Analytics, which represents the most widely used source for bibliometric analysis and reviews, as it contains a wide range of peer-reviewed journals and editorial collections. Since blockchain constitutes an emerging technology and the related published academic literature is still scarce/immature, we opted for a more inclusive design than usual, including proceeding papers in our search, to avoid overlooking the rising academic debates (see, for example, Wang *et al.*, 2021).

To identify the existing literature on the use of blockchain technology in the agri-food sector, we employed the topic search strategy limiting the set of publications to those containing the following Boolean combination: "block*chain* AND (agri* OR farm* OR rural* OR food)", under Business, Economics and Management categories and over a time span from 2008 to 2022. The final sample yielded a set of 178 contributions. The selected pool of publications marks the novelty of this research field, which stems from collaborative investigations and a growing interest from scholars in emerging countries (see Table 1). The academic debate on blockchain and agri-food appears significantly dispersed across 101 editorial sources, with about 20% of the publications grouped among the five most relevant journals encompassing different fields, such as operations and technology management, operations research and management science, innovation and other cross-sectoral journals.

Interest in the applications of blockchain technology in agri-food blossomed in 2017, as depicted in Figure 1. From 2017 to 2022, academic output has increased exponentially, with an annual percentage growth rate of 71.88%, but it still represents an academic niche, especially in economics, business and management. The temporal evolution of the literature suggests the domain, which has not yet entered its maturity phase, will continue to draw more research in the coming years.

Most of these papers (114) are published in journals included in the Association of Business Schools (ABS) Journal Guide 2021[1] and a third of them (52) are in top-tier journals. The distribution is skewed towards journals of operations and technology management (46), innovation (12), operations research and management science (11), information management (9) and cross-sectoral journals (14). Overall, these publications have produced descriptive (69), quantitative (34), prescriptive (29), qualitative (29), experimental (15) and conceptual (2) studies.

3. Findings

3.1 The keyword co-occurrence bibliometric analysis

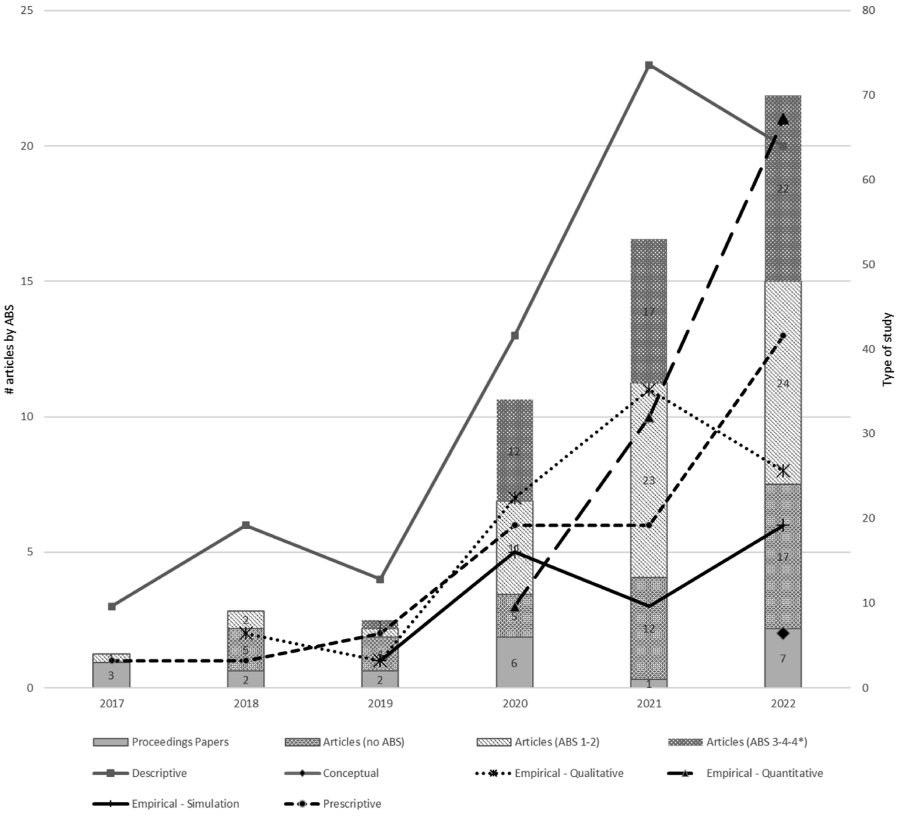
In order to determine the primary areas of research and their paths, we performed a co-occurrence analysis on the authors' keywords and the Keyword Plus identified by WoS Clarivate [2]. Various studies have explored the effectiveness of Keywords Plus for

Description	Results
Main information about data	
Timespan	2017:2022
Documents	178
Annual Growth Rate	71.88%
Average citations per documents	22.88
Document average age	2.15
Document types	
Articles	157
Proceedings papers	21
Documents content	
Author's keywords	563
Keywords Plus	335
Authors	
Authors	523
Author appearances	604
Authors of single-authored documents	21
Authors of multi-authored documents	502
Documents per author	0.3
Max. Number of documents per author	5
Authors collaboration	
Single-authored documents	21
Authors per document	2.9
Co-Authors per documents	3.4
Collaboration index	3.2
Country scientific production	
India	87
United Kingdom (UK)	59
China	59
United States of America (USA)	48
Turkey	25
Italy	16
Total number of countries involved	50
Sources	
Sources	101
Most relevant sources and their field[a]	
British Food Journal (Cross-sector)	10
IEEE Transaction on Engineering Management (Ops and Tech Management)	9
Logistics-Basel	7
Annals of Operations Research (Ops Research and Management Science)	6
Technological Forecasting and Social Change (Innovation)	6

Note(s): [a]AJG2021 ranking
Source(s): Authors' elaboration

Table 1. Descriptive information on the collected publications

bibliometric analyses investigating the knowledge structure of scientific fields. While they are both commonly selected as units of analysis, Keyword Plus terms derive from an unparalleled indexing process that combines traditional Author Keywords with title information from cited references in bibliographic records (Garfield and Sher, 1993). As such, they are more broadly descriptive and comprehensive as a parameter for capturing the content and scientific concepts presented in articles (Zhang *et al.*, 2015). The larger number of

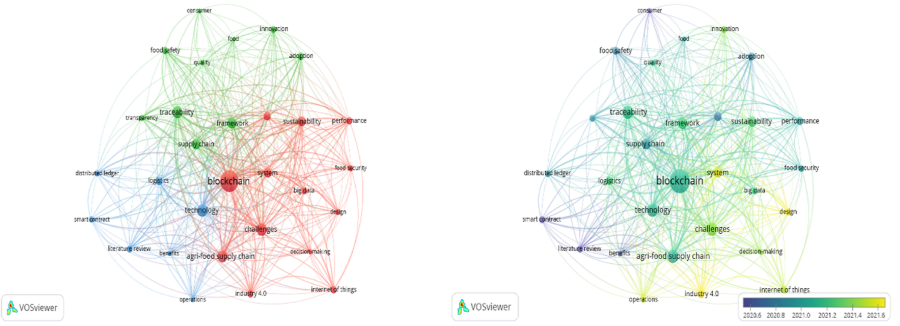


Source(s): AJG2021 ranking
Authors' elaboration

Figure 1.
Time distribution of articles and proceedings papers during the period 2008–2022 per journal ranking[a] and document type ($N = 178$)

Keyword Plus terms and their broader meanings confer several advantages in bibliometric analyses of the structure of scientific fields. Thus combining both sources combination can reveal more details about the content of an article. To improve the significance of the keyword set and avoid repetitions, we consolidated the data merging abbreviation and their full counterpart – that is "IoT" and "Internet of Things" –, synonyms and plurals – that is "Blockchain" and "Blockchain technology" – and correct misspellings – that is "Industry 4" and "Industry 4.0" (Van Eck and Waltman, 2014). We set a minimum threshold of seven occurrences for the keywords, thus restricting the representation to 30 keywords grouped into three distinct clusters, with 361 links and 1760 total link strengths (see Figure 2(a), network visualization).

Each node (circle) represents a keyword whose size signals its prominence in terms of the number of occurrences in the sample. The strength of the connections between keywords is defined by the thickness of the lines between nodes and indicates the number of publications in which two terms recur together. Also, words that co-occur most often are clustered close to each other in the color-based visualization (Van Eck and Waltman, 2014). In the next paragraph, we discuss the content of papers linked to each cluster adopting in-depth systematic lenses.



Network visualization
(a)

Overlay visualization
(b)

Source(s): Authors' elaboration

Figure 2.
VOSviewer co-occurrence analyses

3.1.1 Cluster 1 [red]. Digital technologies for grand challenges. This cluster focuses on firms' perspectives on integrating disruptive technologies to address grand challenges, such as food security and sustainability, and identifying the enabling factors and barriers to technology adoption as drivers of a more sustainable supply chain management. Disruptive digital technologies collaborating in an integrated working environment – such as Blockchain, Internet of Things (IoT) and RFID – have the potential to create sustainable agri-food production systems that alleviate social and environmental concerns (e.g. Kaur, 2019). Emerging technologies can address inefficiencies recorded along the supply chain – causing massive food losses and waste and threatening global food security – and improve industry resilience in the face of turbulences (e.g. Bechtsis *et al.*, 2021). Moreover, the integration of digital technologies into the supply chain has significant social and economic impacts, as it contributes to improving the condition of small-scale producers in rural and peripheral areas of the world, who often find themselves in conditions of poverty, vulnerability and marginalization, at the mercy of powerful multinational actors (e.g. Chaudhuri *et al.*, 2023). On the other hand, monitoring all production and distribution parameters through the use of digital technologies, such as energy consumption and greenhouse gas emissions, can reduce the environmental impact of the agri-food supply chain, which is responsible for a good percentage of pollutant emissions worldwide (e.g. Asif *et al.*, 2022). However, companies that wish to adopt new digital technologies as a driver of sustainability face several problems and resistance forces that hinder their implementation and use. Through Multi-Criteria Decision-Making techniques, many works identify barriers, such as technological, organizational, contextual, relational, economic and social, to digital technology adoption (e.g. Mangla *et al.*, 2022). Specifically, the lack of common protocols and standards between countries prevents coordination for traceability at a global level. The high cost of adopting the technology determines whether or not to integrate it within the supply chain, especially in a sector like agri-food, which suffers from intense pressures to maintain low prices. In addition, shallow digital knowledge and unwillingness to share information on product quality, such as fertilizer and pesticide use, result in smallholder farmers' resistance to change. Nevertheless, the adoption of disruptive technologies would benefit different actors along the supply chain. For example, banks, insurance companies and financial institutions, generally reluctant to grant firms credit because they have no credit history, would be able to monitor their activities and thus prove their financial strength and reliability (Rijanto, 2020).

3.1.2 Cluster 2 [green]. Blockchain technology to gain consumer's trust. This cluster focuses on Industry 4.0 technologies as tools to improve the agri-food supply chain's traceability and ensure food quality for consumers. Consumers are increasingly aware of what they buy and seek information on the origin of food. However, knowing their history is often tricky as supply chains are complex and products travel through vast networks of operators, even across national borders (Bumblauskas *et al.*, 2020). Blockchain-based solutions, coupled with other Industry 4.0 technologies, have the potential to trace the origin of food products throughout the supply chain, ensuring quality and safety for the final consumer. Indeed, digital technologies enable supply chains to be highly connected, efficient and responsive to customer needs and sustainability requirements (Kayikci *et al.*, 2022). Information about product provenance, production, transportation and storage reduces risk perception and enables informed purchasing decisions (e.g. Dionysis *et al.*, 2022). In addition, digital systems can also be a solution to food scandals and foodborne outbreaks. A good traceability system can help track down a food contamination problem early in the supply chain, minimizing public health risks and reputational fallout and improving consumer confidence in the food sector. This is particularly important for fresh and perishable foods such as meat, fruits and vegetables (Bumblauskas *et al.*, 2020). Food fraud can also be mitigated through digital technologies. Tamper-proof records of certifications and labels reduce the information gap between consumers and producers and make supply chains less vulnerable to fraudulent behavior, building trust among participants (Yi *et al.*, 2022).

3.1.3 Cluster 3 [blue]. Blockchain technology beyond cryptocurrencies. In this group, the literature highlights the use of blockchain technology in supply chains of different industries and logistics services, with particular attention to technical features and specific technology tools, that is distributed ledger or smart contracts. Many researchers agree that blockchain technology has a vast potential to transform the supply chain of different industries, such as agri-food or healthcare, by making it transparent, efficient and resilient due to its characteristics and the tools it uses (e.g. Erol *et al.*, 2021). Indeed, since the blockchain consists of a distributed, decentralized and immutable ledger, it allows transactions between users of the same network to be recorded in blocks, linked together and protected by cryptography, ensuring the visibility and security of exchanges of goods and values. Transactions recorded in blockchain technology were designed to be public (without permission). However, in the context of supply chain management, platforms that can provide for the participation of only specific users emerged. For example, permissioned blockchains are particularly suitable for tracking luxury goods because they make private transactions invisible but correctly verified, preventing sensitive data from falling into the wrong hands (Gietzmann and Grossetti, 2021). Another recent technological evolution related to blockchain is the development of smart contracts. Smart contracts are computerized transaction protocols between two or more parties that contain the agreed terms of a transaction. The transaction is executed automatically without intermediaries when predetermined terms and conditions are met. In this way, transaction management takes place faster and at a lower cost (Guerra and Boys, 2022).

In Figure 2(b), we switch to an overlay visualization of keyword co-occurrence, where the color gradient reflects the average year of publication of the documents in which the most used keywords were used. The transition of colors highlights the temporal dynamics of the topics covered: colors from dark blue to dark green correspond to older topics, while the colors from light green to yellow correspond to more recent topics. As expected, early work in this research area deals with blockchain technology as a critical component of cryptocurrencies (e.g. Gietzmann and Grossetti, 2021). More recent works consider the role of blockchain technology in making the agri-food supply chain democratic and climate neutral, overlapping with the first red cluster (e.g. Chaudhuri *et al.*, 2023). The latest papers investigate the factors conditioning the adoption of the technology and present traceability

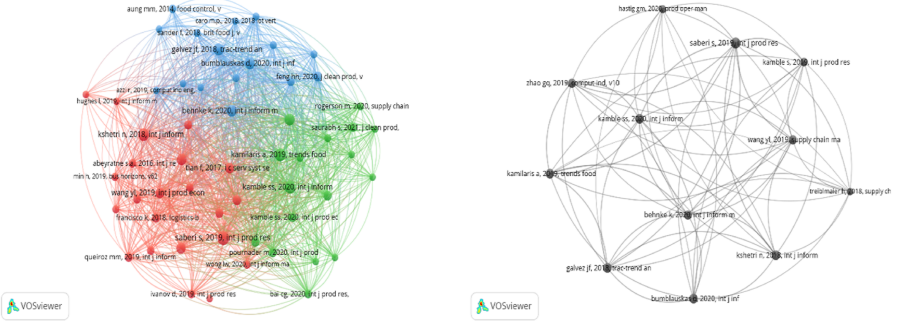
systems based on the integration of blockchain with other disruptive technologies to address several grand challenges, such as alleviating poverty of small-scale producers in rural areas, food loss and food waste and to improve the resilience of the sector in emergencies (e.g. Kör *et al.*, 2022).

3.2 The co-citation bibliometric analysis and the theoretical underpinnings

In Figure 3(a), we illustrate the intellectual roots of the research area and the identification of its fundamental works. Each node (circle) of the bibliometric network represents a cited publication, while the links between the nodes represent the number of times the citations appeared together in the articles of the dataset (Van Eck and Waltman, 2014). The co-citation analysis indicated the presence of 8,987 references, of which only 55 have at least 15 citations [3]. The convoluted network representation makes the identification of distinct clusters cumbersome despite each group being marked with different colors. This configuration suggests that research on blockchain in the agri-food sector is still in its infancy and has not developed sufficiently to constitute distinct thematic streams. To clearly define the topics covered in the clusters, we limited our analysis to the twelve most co-cited articles (Figure 3(b)) and their detailed content (see Table 2 for a summary).

This subsample of papers highlights that the use of blockchain technology leads to the reorganization of supply chains, resulting in changes in intra- and inter-company organizational structure, competitive strategy and operations management of production processes and services. Most of the co-cited articles (10 out of 12) do not refer to any theoretical framework but describe the benefits and challenges of technology adoption. On the contrary, Treiblmaier (2018) rigorously discusses the implications through the lenses of the New Institutional Economy theories. Kamble *et al.* (2019), on their side, study how blockchain applications and related usage difficulties influence the behavioral intention to adopt this technology.

Broadly used theories in the field of innovation pursue a "process approach" and contribute to describing benefits, challenges and decision-making processes leading to individuals' acceptance and adoption of blockchain technology. Specifically, some articles (16) refer to various psychological theories and models related to the behavioral intention of stakeholders and consumers, such as the Theory of Planned Behavior (TPB) (Ajzen, 1991). Alongside these, other articles (3) adopt the sociological perspective of Institutional theory



Network visualization
(a)

Twelve most co-cited articles
(b)

Source(s): Authors' elaboration

Figure 3.
VOSviewer co-citation analyses

Table 2.
Details of co-cited articles

Authors	Year	Title	Journal	Field[a]	Local citations	Article type	Blockchain application	Focus
Saberi, S., Kouhizadeh, M., Sarkis, J., and Shen, L	2019	Blockchain Technology and Its Relationships to Sustainable Supply Chain Management	*International Journal of Production Research*	Ops and Tech Management	51	Conceptual	Sustainability	Benefits and challenges
Kamble, S.S., Gunasekaran, A., and Sharma, R	2020	Modeling the blockchain enabled traceability in agriculture supply chain	*International Journal of Information Management*	Information Management	42	Review/ Empirical (qualitative)	Agri-food supply chains	Benefits
Kamilaris, A., Fonts, A., and Prenafeta-BoldúF.X.	2019	The Rise of Blockchain Technology in Agriculture and Food Supply Chains	*Trends in Food Science and Technology*		42	Review	Agri-food supply chains	Benefits and challenges
Kshetri, N	2018	Blockchain's Roles in Meeting Key Supply Chain Management Objectives	*International Journal of Information Management*	Information Management	41	Review	Supply chains	Benefits
Galvez, J.F., Mejuto, J.C., and Simal-Gandara, J	2018	Future Challenges on the Use of Blockchain for Food Traceability Analysis	*TrAC - Trends in Analytical Chemistry*		40	Review	Agri-food supply chains	Benefits and challenges
Bumblauskas, D., Mann, A., Dugan, B., and Rittmer, J	2020	A Blockchain Use Case in Food Distribution: Do You Know Where Your Food Has Been?	*International Journal of Information Management*	Information Management	39	Empirical (simulation)	Agri-food supply chains	Benefits
Behnke, K., and Janssen, M. F.WH.A.	2020	Boundary Conditions for Traceability in Food Supply Chains Using Blockchain Technology	*International Journal of Information Management*	Information Management	36	Empirical (qualitative)	Traceability	Benefits and challenges

(*continued*)

Table 2.

Authors	Year	Title	Journal	Field[a]	Local citations	Article type	Blockchain application	Focus
Wang, Y., Han, J.H., and Beynon-Davies, P	2019	Understanding Blockchain Technology for Future Supply Chains: A Systematic Literature Review and Research Agenda	*Supply Chain Management*	Ops and Tech Management	36	Review	Supply chains	Benefits and challenges
Zhao, G., Liu, S., Lopez, C., Lu, H., Elgueta, S., Chen, H., and BoshkoskaB.M.	2019	Blockchain Technology in Agri-Food Value Chain Management: A Synthesis of Applications, Challenges and Future Research Directions	*Computers in Industry*	Ops and Tech Management	34	Review	Agri-food supply chains	Benefits and challenges
Kamble, S., Gunasekaran, A., and Arha, H	2019	Understanding the Blockchain Technology Adoption in Supply Chains-Indian Context	*International Journal of Production Research*	Ops and Tech Management	31	Empirical (quantitative)	Supply chains	Adoption behavior
Hastig, G., and Sodhi, M	2019	Blockchain for Supply Chain Traceability: Business Requirements and Critical Success Factors	*Production and Operations Management*	Ops and Tech Management	26	Review	Traceability	Benefits and challenges
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*	Ops and Tech Management	25	Conceptual	Supply chains	Supply chain reengineering post adoption

Note(s): [a]AJG2021 ranking
Source(s): Authors' elaboration

(DiMaggio and Powell, 1983) to explain the role of institutions in motivating business adoption of technology.

A more limited strand of studies sees blockchain technology as a tool to prevent the opportunism that characterizes global agri-food markets in favor of sustainability and create new areas of competitive advantage through unique resources and firm capabilities. Some studies (6) build on corporate strategy theories, such as Agency Theory (Eisenhardt, 1989), which help explain how secure exchanges and information flows made accessible by blockchain technology change business organizational boundaries and reduce asymmetric information problems typical of buy and sell contracts, generating potentially efficient supply chains. Through the Resource-Based View (Penrose, 1959), some papers (4) focus on the technologies' value for reallocating resources in favor of the most disadvantaged producers and the performance of the entire food chain. Instead, through the Dynamic Capabilities theory (Teece *et al.*, 1997), others (2) explain how to manage a dynamic value chain by integrating and reconfiguring agri-food product information. Finally, a narrow group of studies (5) links corporate strategy to performance, using game theoretical modeling to study strategic interactions between agri-food chain agents with different objectives.

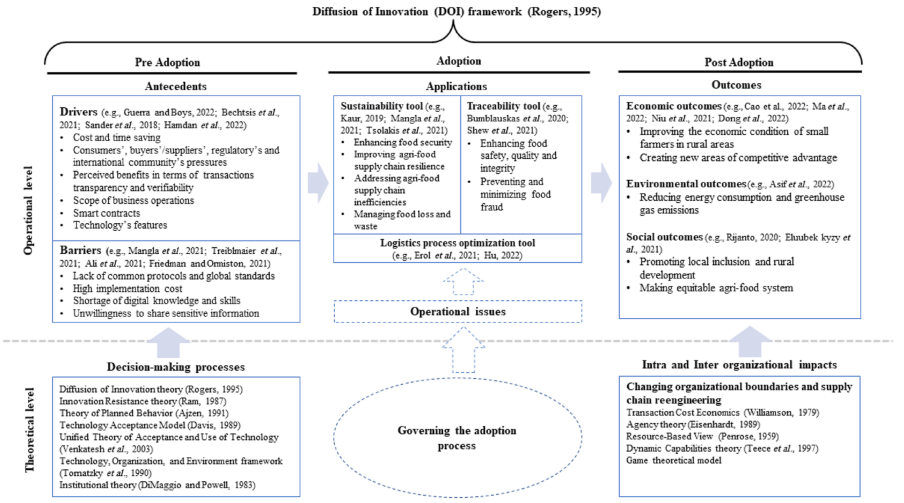
Papers containing theoretical underpinnings (28) come from influential and established journals included in the ABS Journal Guide 2021, as these sources are widely recognized for shaping ongoing research on theoretical issues and defining new research horizons (Thomas and Tee, 2022). While these articles build upon a variety of theories derived from innovation, strategy and organizational studies, the most common field of publication is operations. This evidence confirms that supply chain management is the most popular topic in this research area, borrowing theoretical lenses from different disciplines (Walker *et al.*, 2015).

4. Discussion

Our analyses revealed essentially the following elements that characterized the deployment of literature on blockchain in agri-food sector: (1) from a methodological point of view, the research domain provided literature or pilot implementation reviews and empirical studies; (2) from a conceptual point of view, the domain studied technical, operational, ethical and behavioral issues to improve supply chain management; (3) from a theoretical point of view, the domain involved theories widely adopted in innovation, strategy and organization fields.

Despite heterogeneous perspectives and approaches, we reorganized extant knowledge into a comprehensive conceptual map that draws upon the systemic framework of the Diffusion of Innovation (DOI) theory (Rogers, 1995) reckoning three macro-areas: (1) *pre-adoption* or antecedents – that is knowledge, persuasion and the decision to adopt or reject a new technology –, (2) *adoption* and (3) *post-adoption* or outcomes. Consistently with this framework, Figure 4 reveals that agri-food enterprises adopt blockchain technology following a sequential, step-by-step process.

First, each organization evaluates the blockchain technology in an exploratory phase (*pre-adoption*) through an individual sense-making process to recognize whether this technology can meet its needs and be socially accepted and rewarded by its community. Based on innovation theories, the extant literature has identified organizational, environmental and technological factors that may encourage or discourage technology acceptance and adoption. Time and cost savings in production, international pressures, perceived benefits in terms of verifiability and transparency, broadening the scope of business operations, technology features and tools such as smart contracts emerged as drivers for technology adoption (e.g. Guerra and Boys, 2022; Bechtsis *et al.*, 2021). Conversely, lack of international protocols and standards, high implementation costs, lack of digital knowledge and skills and reluctance to share sensitive information emerged as barriers to technology use (e.g. Mangla *et al.*, 2022).



Source(s): Authors' elaboration

Figure 4.
Conceptual map

Secondly, each organization decides whether and how to implement the technology (*adoption*). From our review, we identified many pilot implementations to address grand challenges threatening global food security (e.g. Kaur, 2019), gain consumer trust (e.g. Bumblauskas *et al.*, 2020) and optimize intra- and inter-firm logistics operations (e.g. Erol *et al.*, 2021). As such, blockchain technology has emerged at the operational level as a sustainability, traceability and logistics tool. However, blockchain realization requires careful planning to re-engineer processes and govern change while ensuring the organization's operational continuity. At this stage, it is unclear how companies govern the adoption of the technology to successfully integrate it internally. In this regard, Figure 4 reveals a significant gap in the theoretical foundation of existing literature, as highlighted in the dotted boxes.

In the concluding stage of the adoption process (*post-adoption*), organizations review their experience and solidify their decision by assessing the outcomes in terms of their economic, environmental and social impact. The theories of strategy and organization offer a structure for conducting empirical studies to determine the impact of technology on reducing greenhouse gas emissions and conserving energy (e.g. Asif *et al.*, 2022), fostering rural inclusion and development (e.g. Rijanto, 2020), improving the economic circumstances of small rural producers and identifying potential areas for gaining a competitive edge (e.g. Cao *et al.*, 2022).

The current stage of theorization in our research domain signals its early development, which is evident in the distribution of prior studies within the conceptual framework. This situation, however, unveils a compelling opportunity for future research activities. Specifically, strategic perspectives on blockchain technology, focusing on the rationale behind changes in corporate organizational boundaries and the ensuing reallocation of resources, call for empirical scrutiny (Treiblmaier, 2018). Our advocacy extends to a more profound exploration of how blockchain can effectively address critical issues within small agri-food organizations, underscoring its potential to alleviate poverty and marginalization (e.g. Chaudhuri *et al.*, 2023).

While the literature predominantly concentrates on decision-making processes leading to blockchain adoption in agri-food companies, a substantial gap remains in understanding

subsequent implementation phases and the overall innovation process (Dionysis *et al.*, 2022). Although existing studies have primarily centered on factors driving blockchain adoption, there is a distinct dearth of comprehensive insight into how companies successfully integrate this technology into their internal operations. Furthermore, the economic, societal and environmental impacts of blockchain adoption still await thorough exploration.

In addition, strategic interactions between actors in the agri-food sector for blockchain adoption remain underexplored, necessitating a multi-actor perspective to comprehensively examine the supply chain and its participants (e.g. Cao *et al.*, 2022). The investigation into collaborative arrangements and strategic alliances to expedite blockchain diffusion in remote rural areas, recognized for their resistance to innovation, offers a captivating avenue for research on social and economic development, along with understanding the leadership's role in governing adoption (Rijswijk *et al.*, 2021).

We suggest that the exploration of these theoretical constructs can advance simultaneously by addressing three units of analysis and corresponding research questions: (1) individual level, examining the behaviors of consumers, managers and entrepreneurs; (2) company level, scrutinizing the internal structures of organizations and (3) network level, evaluating group dynamics and higher-level processes such as communities and ecosystems. To attain a comprehensive understanding, we advocate for the integration of complementary theories spanning behavioral and organizational frameworks, which can elucidate governance structures and inter-organizational relationships (Halldórsson *et al.*, 2007). Given the scarcity of empirical studies, both qualitative and quantitative approaches, including simulations, are essential for validating and generalizing insights from theoretical studies (e.g. Sahoo *et al.*, 2022).

Furthermore, we reiterate the importance of considering blockchain alongside other complementary technologies like the internet of Things (IoT), Big Data and Cloud Computing. This integrated approach has the potential to establish real-time connected agri-food chains, enriching the quality of information and furnishing organizations investing in such technologies with a competitive edge (e.g. Kayikci *et al.*, 2022). The exploration of these integrated technologies deserves further attention in future research endeavors.

5. Conclusions

While academic research on blockchain technology in the agri-food sector has seen a noticeable increase, a paucity of retrospective work remains. This study addresses this gap by contributing insights into the immaturity of the research domain and its predominant focus on operational issues. Furthermore, it enhances the state-of-the-art by combining quantitative and qualitative techniques and offering a nuanced understanding of the investigated phenomenon. As such, our research is beneficial for scholars seeking to identify new topics, address potential gaps, formulate impactful research questions and position their work within cutting-edge literature.

Our investigation delves into the genesis and evolutionary dynamics of knowledge concerning blockchain in agri-food within business-related research areas. The findings of our review align with those of Pandey *et al.* (2022) and Dal Mas *et al.* (2023) by identifying key thematic areas and emphasizing the significance of integrating various emerging technologies. However, our review extends the existing retrospective literature by comprehensively describing the covered topics, their evolution and their theoretical underpinnings. Specifically, the study highlights that the focus of scholars has gradually shifted from technology *per se* and its cross-sectoral uses to technology as a tool to increase consumer confidence and achieve sustainability of agri-food systems. Also, it reveals that although operations and information management areas constitute the roots of the domain, addressing factual issues with atheoretical and interdisciplinary contributions, more

recently the literature has opened to innovation, strategy and organization research areas. In practical terms, our study contributes operational concepts to the framework, further enriching the understanding of blockchain adoption in the agri-food sector.

Despite the substantial contributions, our study acknowledges limitations arising from methodological choices. Specifically, the reliance on the Web of Science database for document identification introduces potential bias. The qualitative analysis may also exhibit variations based on individual researchers' expertise. Although cross-checks were conducted among all authors, inferences remain influenced by the research team's collective expertise and perceptions of promising avenues for future research. Nevertheless, we anticipate that this review will provide researchers with fresh perspectives and original ideas, propelling the knowledge frontier regarding blockchain adoption in the agri-food sector.

Notes

1. This guide illustrates the field and relative quality of journals in which business and management scholars publish (Association of Business School, 2021).
2. Keywords Plus are words or phrases that recur frequently in the titles of article references, generated by an automatic computer algorithm exclusive to Clarivate databases (Garfield, 1990).
3. The choice of this limit is justified by the fact that the co-citation analysis aims to determine the most important basic studies on the subject (Small, 1973).

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