Title: The potential for Blockchain to improve small-scale agri-food supply chain resilience: A systematic review.

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Abstract

Purpose

We conducted a systematic review to explore the potential for the application of Blockchain technologies for supply chain resilience in a small-scale agri-food business context.

Findings

The systematic review of articles (n=57) found that the use of Blockchain technology in the small-scale agri-food business sector can reduce the risk of food fraud by assuring the provenance of food products.

Research limitations/implications

Only a few papers were directly from a small-scale agribusiness context. Key challenges that limit the implementation of Blockchain and other distributed ledger technologies include concerns over the disclosure of proprietary information and trade secrets, incomplete or inaccurate information, economic and technical difficulties, low levels of trust in the technology, risk of human error and poor governance of process-related issues.

Originality/value

The application of Blockchain technology ensures that the risks and costs associated with non-compliance, product recalls, and product loss are reduced. Improved communication and information sharing can increase resilience and better support provenance claims and traceability. Better customer relationships can be built, increasing supply chain efficiency and resilience.

Keywords: Supply chain resilience; Blockchain technology; disruptions; COVID-19; small-scale agri-food business, traceability.

1. Introduction

Increased global disruption experienced by businesses, including the COVID-19 pandemic (Zhu et al., 2020, Marusak et al., 2021, Guaita Martínez et al., 2022), have led to calls for improved supply chain resilience (Alabi and Ngwenyama, 2023), especially for small-scale agri-food businesses that have limited capabilities to deal with such disruptions (Bak *et al.*, 2020, Aslam *et al.*, 2020). Supply chain resilience can be defined as the "capability of a supply chain to develop the required level of readiness, response, and recovery capability to manage disruption risks, get back to the original state or even a better state after disruptions" (Chowdhury Md Maruf *et al.*, 2019, p. 659). These frequent disruptive events point to the unpredictability of contemporary interconnected globalised markets (Duong and Chong, 2020).

Disruption risk describes the unplanned occurrences that limit the stability, agility, and flexibility of a supply chain because of natural events or man-made disasters such as hurricanes, floods, pest infestations (e.g., locusts), economic recession, terrorist attacks, labour strikes, and technological changes (Parast and Shekarian, 2019). Risks encountered in the supply chain create obstacles to attaining operational excellence (Wang *et al.*, 2020, Kleindorfer and Saad, 2005). Therefore, managing such risks is crucial for organisational sustainability and resilience building (Manning, 2023, Chowdhury *et al.*, 2023, Christopher and Peck, 2004, Martin and Matthias, 2011).

Resilience allows supply chains to recover from disruptions faster (Aslam *et al.*, 2020, Lohmer *et al.*, 2020). Hence, food supply chains must be able to predict future stressors and shocks as well as the opportunities to bounce back should they occur (Misselhorn *et al.*, 2012). A resilient food supply chain has the capabilities for adaptability, alignment, and agility in each component of the four supply chain areas of knowledge management, collaboration, logistics, and sourcing (Manning and Soon, 2016) as supply chain management goes beyond just economic issues to incorporate environmental and social issues too (Lis *et al.*, 2020, Zhu *et al.*, 2020).

Previous studies on promoting food supply chain resilience have focused on the application of Blockchain technology to large-scale agri-food businesses and positioned Blockchain technology as a means of achieving collaboration, traceability, transaction transparency and security (Chin *et al.*, 2022, Shew *et al.*, 2022, Marusak *et al.*, 2021). However, limited attention is given to the application of Blockchain technology to small-scale agri-food businesses (Enescu and Ionescu, 2020), despite the essential role of these businesses in the global food system. This leaves a gap in our theoretical and practice-based understanding of the implications of Blockchain technology for small-scale agri-food businesses that lack the capabilities to be resilient in a turbulent supply chain system (Motta *et al.*, 2020, Song *et al.*, 2020, Xiong *et al.*, 2020). Indeed, determining how the adoption of Blockchain technology offers different opportunities and challenges for small-scale agri-food businesses in particular, and the implications in terms of the agility of response to supply chain disruption is important. Therefore, the purpose of this research is to address this gap by exploring the implications of Blockchain technology for small-scale agri-food businesses and how such technology can enhance resilience in the supply chain. Hence, the research questions that emerge are:

RQ1. Can Blockchain technology improve supply chain resilience for small-scale agri-food businesses?

RQ2. What features of supply chain resilience may Blockchain technology improve for small-scale agri-food businesses?

RQ3. What implementation challenges do small-scale agri-food businesses encounter with Blockchain technology?

We argue that answering these questions is very relevant to these businesses who, since 2019, have been exposed to various single and aggregate shocks emerging from global events. Indeed, the growing body of literature that is considering the occurrence of disruptive events, such as the conflict in Ukraine, and the Covid-19 pandemic, and their short and long-term impact on global sourcing (including Allam *et al.*, 2022, Jagtap *et al.*, 2022, Manning, 2023) demonstrates supply chain vulnerability to a diverse range of risks (Christopher and Peck, 2004, Fiksel *et al.,* 2015, Habermann *et al.,* 2015). For small-scale agri-food businesses to remain competitive in their supply chain(s), amidst exposure to shocks, they must be more responsive to disruptions and be agile in identifying opportunities to remain resilient (Battistella *et al.,* 2017, Yang, 2014, Mostafa *et al.,* 2020). Hence, the central argument of this research is that Blockchain technology holds untapped potential for small-scale agri-food businesses, and its adoption can significantly contribute to their ability to maintain resilience within food supply chains.

This study, therefore, uses a systematic review approach to explore previously published work on the application of Blockchain for food supply chain resilience to develop (1) an understanding of the potential of Blockchain technology to improve the resilience of small-scale agri-food business within supply chains (RQ1, RQ2), and (2) to identify the Blockchain technology implementation challenges that small-scale agri-food businesses face (RQ3). Our findings contribute to extant literature by identifying how the use of Blockchain technology can support small-scale agri-food business' resilience. This includes assuring the provenance of food products, improving traceability, and reducing the costs associated with non-compliance (Rejeb *et al.*, 2020).

Key challenges identified in this review that limit the implementation of Blockchain and other distributed ledger technologies (DLTs) for small agri-food businesses include concerns over trade and business secrets disclosures (Rogerson and Parry, 2020, Rejeb *et al.,* 2020, Tharatipyakul *et al.*, 2022), incomplete or inaccurate information (Tharatipyakul *et al.*, 2022), and economic and technical challenges (Compagnucci *et al.*, 2022), including the high cost of establishment and maintenance (Rejeb *et al.*, 2020). Other challenges include high transaction and information management costs (Chu and Pham, 2022), unwillingness to pay for the technology, lack of trust in the technology, human error, and concerns over governance of process-related issues (Rejeb et al., 2020, Rogerson and Parry, 2020). These findings offer insights and recommendations for policymakers, industry stakeholders, and small-scale agri-food businesses on how to harness Blockchain technology to enhance their resilience and competitiveness in the supply chain.

The rest of the paper is structured as follows: section 2 gives an overview of the application of Blockchain technology. In section 3, we present the systematic literature review approach and in section 4 we highlight the findings. The discussion, conclusions and future research directions are presented in sections 5 and 6.

2. Application of Blockchain Technology: An overview

Blockchain comprises of traceable and immutable digital records of transactions accessible to a network of participants (Crosby *et al.*, 2016, Treiblmaier, 2020, Lashkari and Musilek, 2021). Blockchain supports a secure, transparent, and timely exchange of data and process automation through intelligent contracts (Lohmer *et al.*, 2020, Leible *et al.*, 2019), storing data in a set of 'blocks' with each block containing several time-stamped transactions (Glaser, 2017, Wang and Luo, 2019). It combines concepts and technologies proposed by Satoshi Nakamoto when introducing Bitcoin two decades ago (Narayanan and Clark, 2017).

The Blockchain ledger is distributed and shared across all the nodes in the Blockchain network with each node having access to the current version of the ledger (Ahmed and MacCarthy, 2022). It is a consensus mechanism that enables all participants (nodes) in the network to agree on the state of the Blockchain, validate transactions, and determine which transactions should be added to the ledger (Wang *et al.*, 2019). The central notion of Blockchain technology adoption is the consensus mechanism used for information flow management. For instance, in their work, Zhong et al. (2023) introduced a pragmatic Byzantine fault-tolerant consensus algorithm designed to assess the credibility of enterprise nodes, enhance the selection process for master nodes, and guarantee both high efficiency and cost-effectiveness. Other consensus mechanisms reported in literature include Proof of Work (PoW), and Proof of Authority (PoA) (Tian, 2016, Bala and Kaur, 2022).

The different types of Blockchain, the mechanisms, and how Blockchain works have been studied (for example, Ahmed and MacCarthy, 2022, Treiblmaier, 2020, Pilkington, 2016, Morkunas *et al.*, 2019). So the power, uniqueness, and attractiveness of Blockchain originate from the combination of its diverse features to support different applications (Casino *et al.*, 2019), extending beyond cryptocurrencies (Eklund and Beck, 2019, Treiblmaier, 2020) to different sectors (Treiblmaier, 2020, Chang and Chen, 2020, Nguyen et al., 2021, Lu et al., 2022). Blockchain technology has been applied to the agricultural sector in different areas. For example, there are software platforms such as AgriDigital and Provenance designed to assist in the transaction and settlement of agricultural commodities and to manage supply chain risks. Early application of Blockchain in agriculture, and more generally, dates back to 2016 (Rocha *et al.*, 2021, Casino *et al.*, 2019, Gurtu and Johny, 2019). Blockchain has been applied with greater advantages that support traceability systems (Demestichas *et al.*, 2020, Köhler and Pizzol, 2020), transparency (Köhler and Pizzol, 2020, Liu *et al.*, 2021), and better management of transaction times (Bermeo-Almeida *et al.*, 2018) compared to technologies like the traditional centralised database. However, conceptual connections of the application of Blockchain with improved resilience have been lacking.

Resilience strategies in supply chain management such as lean production, just-in-time logistics and global sourcing reduce the costs of doing business, but can also reduce organisational agility when faced with higher levels of uncertainty and disruption (Fiksel *et al.,* 2015). As a result of the risk of disruption(s) to globalised supply chains, some scholars have advocated for a change in procurement processes such as dual sourcing (Zhu *et al.,* 2020, Fujimoto and Park, 2014) while others propose 'single sourcing' from one supplier and developing deeper supply chain relationships (Whitney *et al.,* 2014, Ergun *et al.,* 2010). Taking advantage of improved quality control, fraud risks and cost reduction through deeper single relationships alone will not deliver resilience, so alternative sourcing strategies must also be embedded within procurement processes (Christopher and Peck, 2004, Manning *et al.,* 2016).

Improved collaboration could increase flexibility and consequently supply chain resilience (Scholten and Schilder, 2015, Shekarian and Mellat Parast, 2020). Supply chain collaboration has gained wide attention among scholars of supply chain resilience (Duong and Chong, 2020, Christopher and Peck, 2004). However, trust-based relationships are fundamental to successful collaboration (Dubey *et al.,* 2019). Collaboration is likely to be at risk from supply chain disruption, leading to potential distrust among collaborating partners (Duong and Chong, 2020). As part of supply chain collaboration, visibility is also important. Lack of visibility leads to information asymmetry and even opacity (Dubey *et al.,* 2018). Visibility extends beyond traceability (Kowalska and Manning, 2022), ensuring relevant information is accessible to users, both within and outside the organisation to control, monitor and adapt supply chain operations and strategy from service acquisition to delivery (Kamble *et al.,* 2020). Hence, the use of information communication technology to promote visibility has been studied in the supply chain management literature (Kowalska and Manning, 2022, Ergun *et al.,* 2014, Wu *et al.,* 2016), but not specifically in the context of small-scale agri-food businesses. The next section explores the approach adopted for this study.

3. Research approach

3.1. *Systematic review*

Publications relevant to Blockchain technologies' application to food supply chain resilience for small-scale agri-food businesses were sourced using Web of Science, Scopus, and Google Scholar as part of a systematic review being the most widely used databases for such reviews (Aria and Cuccurullo, 2017). We explored articles systematically from a dual perspective (Bargoni et al., 2023); considering the type of paper (conceptual or research papers) and secondly, the paper's theoretical contribution in terms of supply chain sector and the aspects of blockchain application. Older articles on the subject published before the year 2000 were excluded as literature on supply chain disruption(s) started gaining prominence around 2000 (Katsaliaki *et al.*, 2022).

The application of a systematic approach was chosen to ensure that the search aspect of the research is reproducible and represents the existing literature in this area (Guitart *et al.*, 2012, Denyer and Tranfield, 2009). Depth compared to the breadth of the reviewed literature was the focus of the search string based on the Population, Exposure and Outcomes (PEO) framework (Aboagye *et al.*, 2021). Population (P) in this case refer to small scale agri-food business, Exposure (E) refer to Blockchain application while Outcome (O) refer to supply chain resilience. The entire process of identification, selection and categorisation of papers was completed to reduce any potential selective biases as found in narrative reviews (Petticrew, 2001). Hence, conclusions and the addressing of the research questions to be reported were drawn from the literature using this systematic method (Guitart *et al.*, 2012, Sauer and Seuring, 2023).

3.2. Search methodology

A two stage approach to the data extraction was employed based on Bretas and Alon (2021). Firstly, by developing a keyword search and secondly a detailed examination of the papers (Alon et al., 2020). Papers were selected based on the titles, abstracts, and keyword searches to obtain the relevant papers for inclusion in the review. We recorded 6,143 papers at the first level of the search from both Web of Science, Scopus, and Google Scholar search. The following keywords and criteria: “Blockchain” (Title) And Food supply chain (Topic) Or Food supplychain (Topic) Or agricultur* supply chain (Topic) was used. Exclusion and inclusion criteria such as the language of publication, type of article and scope of the study (population being small-scale agri-food businesses) were applied to select the most appropriate papers for the review (Table I) which were reduced to 193 papers. To support the validity and relevance of this approach, two expert librarians were consulted. The librarians supported the co-creation of the search terms, research priorities and the design of this review (Murray *et al.,* 2018, Murray *et al.,* 2021).

Insert Table I here.

Duplicates, conference papers, review papers and articles not related to agri-food supply chain resilience management were excluded. The following information from the selected and reviewed papers was recorded for each one based on Guitart *et al.* (2012): author(s); publication year; resilience management strategies and aspects of Blockchain application. After screening of the title and abstract, the papers included in the review (n=193) were read in full, assessed for eligibility, and 57 papers were specifically considered to be within the context of the research themes about small-scale agri-food businesses Figure 1.

Insert Figure 1 here.

3.3. Data analysis

The papers included in the review were extracted and analysed for the key themes and trends using a Microsoft Excel spreadsheet. To focus on addressing our research questions, we focus on the supply chain sectors and the aspects of Blockchain application. We also considered the location (country) of study, the supply chain risks and resilience measures, the challenges, and the barriers to Blockchain application reported in the literature. The results of the analysis are thematically presented in the next section.

4. Results

4.1. Blockchain in supply chains and reasons for application

Blockchain has been applied in various agri-food sub-sectors and the aspects of application highlighted (Table 2).

Insert Table 2 here:

We found that Blockchain is positioned as providing several benefits in the agri-food sector such as the "ability to share immutable data between supply chain stakeholders and automate agreements and the exchange of trusted information between multiple actors" (Bumblauskas *et al.,* 2020; p. 4). Research also shows that Blockchain can improve farmer visibility to other supply chain actors through organised markets/off-takers (Compagnucci *et al.*, 2022, Enescu and Ionescu, 2020). Among all the studies, only three studies were specifically on small-scale agribusinesses that benefit from blockchain application through cooperative arrangements to increase trust (Mangla *et al.,* 2021, Compagnucci *et al.,* 2022, Lee *et al.,* 2022); with a focus on traceability, food safety and transparency in the case of Mangla et al. (2021).

4.2. Country/location of study

The review revealed that the application of Blockchain to small-scale agri-food business was considered in studies in countries such as Australia, Brazil, China, Columbia, Denmark, Estonia, Greece, Italy, India, Indonesia, Malaysia, Mexico, Netherlands, Palestine, Portugal, Russia, Spain, Thailand, Tunisia, Turkey, Uganda, Ukraine, the USA, Vietnam, and Zambia (Figure 2) based on the 57 papers included.

Insert Figure 2 here:

The next section explores the studies in the papers that consider trust, transparency, accountability, and the application of Blockchain for resilience, the specific focus of the research questions in this study.

4.3. Blockchain and supply chain resilience factors

Blockchain technology has gained significant attention in recent years as a potential solution for improving the resilience of small-scale agri-food business supply chains (Rejeb *et al.*, 2020). Blockchain has the potential to address several key challenges faced by small-scale agri-food businesses, including disruption risk, the lack of trust, transparency, and accountability in the supply chain (Rejeb *et al.*, 2020). A study from the USA reported that Blockchain was applied to reduce the risk of food recalls, fraud, and product loss as products (eggs) were collected from a cluster of 100 small farms specifically by identifying the source of the eggs when issues arose during processing (Bumblauskas *et al.*, 2020). Other studies highlighted that Blockchain could eliminate the risk of food fraud, forgery and counterfeiting; (Robb *et al.,* 2020, Tsolakis *et al.,* 2021, Bandinelli *et al.,* 2023) and reduce the risk of milk spoilage (Mangla *et al.*, 2021).

Blockchain technology can increase supply chain transparency by offering a secure and decentralised platform for information recording and sharing, promoting better coordination, visibility, and trust (Rejeb *et al.*, 2020). Blockchain technology can improve supply chain efficiency and reduce costs in small agri-food business supply networks by eliminating middlemen and enabling a direct exchange of products (Peng *et al.,* 2022, Chu and Pham, 2022). Lucena et al. (2018) reported that Blockchain technology can improve food safety by enabling real-time monitoring of the supply chain, reducing the risk of food contamination, and increasing the speed and accuracy of food recalls. Thus, the literature reviewed contends that Blockchain technology has the potential to strengthen the resilience of small-scale agri-food industry supply chains by raising trust, transparency, and accountability, cutting costs, and improving food safety (Rejeb *et al.*, 2020). These sections have therefore provided insight for addressing RQ1 and RQ2.

4.4. Challenges and barriers to blockchain application

Specific challenges and barriers were highlighted in some of the papers reviewed that militate against successful Blockchain implementation (RQ3). These include concerns over the disclosure of trade secrets (Rogerson and Parry, 2020, Tharatipyakul *et al.*, 2022), incomplete or inaccurate information (Tharatipyakul *et al.*, 2022), and economic and technical challenges (Compagnucci *et al.*, 2022). Other challenges reported include high transaction and information management costs (Chu and Pham, 2022), a lack of willingness to pay for the technology, a lack of trust in the technology, human error, and concerns over governance of process-related issues (Rogerson and Parry, 2020). According to Chu and Pham (2022) despite the significant benefits of applying Blockchain technology to the cashew supply chain in Vietnam, the lack of investment in developing agricultural platforms and Blockchain infrastructure limits its application. In the next section, we discuss the implications of our findings and suggest directions for future research.

5. Discussion

This paper set out to explore the opportunities for Blockchain application for supply chain risk management and resilience in the context of small-scale agri-food businesses especially with regard to vulnerability to disruption (Bak *et al.,* 2020, Aslam *et al.,* 2020), and to secure income for the businesses concerned. Blockchain technology is increasingly receiving attention due to the potential for multiple application and the benefits that can be accrued to small-scale agri-food businesses (Enescu and Ionescu, 2020). Three questions were posed:

RQ1. Can Blockchain technology improve supply chain resilience for small-scale agri-food businesses?

RQ2. What features of supply chain resilience may Blockchain technology improve for small-scale agri-food businesses?

RQ3. What implementation challenges do small-scale agri-food businesses encounter with Blockchain technology?

To answer the first two research questions, the reviewed literature points to two intersecting features of Blockchain technology and supply chain resilience. First are the consensus mechanisms which are crucial for ensuring the security, integrity, and trustworthiness of the Blockchain (Tian, 2016, Bala and Kaur, 2022). Second is Blockchain's secured and decentralised platform which relies on consensus mechanisms for secure and transparent information flow. Supply chain resilience is achieved because the secure decentralised platform minimises disruptions caused by data inaccuracies or intentionally fraudulent activities. In the event of a disruption, the decentralised ledger ensures flexibility, agility, data availability and resilience (Sharma *et al.*, 2021). Through this, blockchain serves as a powerful tool to address pressing concerns surrounding food safety, quality, and authenticity (Manning *et al.*, 2019).

The use of Blockchain could enhance transparency and traceability from 'farm to fork,' a pivotal advancement in the small-scale agri-food business supply chains (Bumblauskas *et al.*, 2020). Food fraud has emerged as a global challenge and risk, threatening the integrity of food products. Blockchain combats this risk by establishing a comprehensive and tamper-proof record of each product's journey (Makarov *et al.*, 2019). This multifaceted transparency could instil consumer confidence, ensuring that food products meet the expected quality and ethical standards. In essence, Blockchain has the potential to provide guarantees of the authenticity of food within the agri-food industry supply chain framework at the small-scale level (van Hilten *et al.*, 2020). This is important as many small-scale farmers and agri-food businesses produce food to feed themselves and also for sale within local or global supply chains (Garrard and Fielke, 2020). Moreover, this study shows that the implication of Blockchain technology extends far beyond consumer trust. By utilising Blockchain technology effectively, small-scale agri-food businesses may experience a significant reduction in risk, both in terms of product related disruptions within the supply chain and the financial consequences of product recalls (van Hilten *et al.*, 2020, Bumblauskas *et al.*, 2020, Lucena *et al.*, 2018, Makarov *et al.*, 2019, Tsolakis *et al.*, 2021). Another risk management strategy that Blockchain technology can enable is the implementation of smart contracts which can be used to automate the execution of contracts, reduce the need for intermediaries and increase the speed of transactions. This can help reduce the fraud risks and errors in the supply chain. The benefits are not solely economic; they encompass the strengthening of consumer-business relationships, a cornerstone of sustainable growth (Joo and Han, 2021).

Efficiency gains materialise through blockchain's streamlined processes for traceability, while the sector's overall resilience is enhanced. Transparency translates into informed decision-making, enabling businesses to adapt and respond effectively to challenges and changing circumstances (Tharatipyakul *et al.*, 2022). Furthermore, by utilising the potential of

Blockchain, many marginalised small-scale agri-food businesses unable to enter international markets can connect directly with buyers through developing small clusters, and also retaining more of the value at farm level, a key target with the delivery of the Sustainable Development Goals (SDGs) (Chandan *et al.,* 2023). These nuanced aspects of Blockchain technology are beneficial to small-scale agri-food businesses because they enhance their market access, revenue, and negotiations' power through reducing information asymmetry. This is a critical aspect to address since small-scale farmers also play such a key role in feeding a significant percentage of the global population (Godfray *et al.,* 2010).

In considering RQ1 and RQ2, one of the key insights derived from this review is the importance of drawing lessons from past supply chain disruption events. The integration of Blockchain technology is highlighted as a promising avenue to enhance supply chain resilience in this context (van Hilten *et al.,* 2020). However, it is crucial to note that the adoption of Blockchain technology is not without its limitations. Privacy-related concerns, particularly the risk of data breaches involving sensitive business information, necessitate a strong emphasis on regulatory compliance (Bumblauskas *et al.,* 2020, Casino *et al.,* 2021, Bertino *et al.,* 2019).

To answer RQ3, this study found certain challenges that affects the implementation of Blockchain technology despite the benefits highlighted. These challenges include concern over trade secrets disclosures (Rogerson and Parry, 2020, Tharatipyakul *et al.,* 2022), incomplete or inaccurate information (Tharatipyakul *et al.,* 2022), and economic and technical challenges (Compagnucci *et al.,* 2022). Other challenges reported include high transaction and information management costs for small-scale agri-food businesses (Chu and Pham, 2022, van Hilten *et al.,* 2020, Chandan *et al.,* 2023), lack of willingness to pay for the technology, lack of trust in the technology, risk of human error, and concerns over governance of process-related issues (Rogerson and Parry, 2020). To address these challenges, there is a need for governance structures to be developed, together with regulatory and consumer buy-in (Brewer *et al.,* 2021).

Also, the potential for human error needs to be addressed as the quality and safety compliance aspects of small-scale agri-food supply chains are important to all relevant stakeholders from producers, processors, regulators, to consumers (Kasten, 2019). Blockchain can act as a bridge to ensure transparency in the quality audit trail. For instance, in dairy supply chains where collectively producers and processors owned or are linked to food testing laboratories as found in a USA-based study (Bumblauskas et al., 2020, Kasten, 2019) and for small scale dairy farmers in Turkey (Mangla et al., 2021).

6. Conclusions

The purpose of this research was to address an existing theoretical gap by exploring the implications of Blockchain technology for small-scale agri-food businesses, challenges to adoption and how the technology can be used to enhance resilience in the supply chain(s) of interest (Rejeb *et al.*, 2020). This approach can then inform future empirical research. There is limited evidence of Blockchain being applied in a small-scale agri-food business context. Where the technology has been applied the focus has been on the areas of traceability, fraud detection and prevention, food safety and transparency (Bumblauskas *et al.*, 2020, Mangla *et al.*, 2021). Improved technology access, greater digital literacy and financial resources can enable opportunities for small-scale agri-food businesses to apply Blockchain technologies for resilience in the event of disruptions in the supply chain (Rejeb *et al.*, 2020). Despite the seeming benefits of Blockchain application for the small-scale agri-food business sector, certain challenges persist that limit application therein (Rogerson and Parry, 2020, van Hilten *et al.*, 2020, Chu and Pham, 2022, Tharatipyakul *et al.*, 2022, Chandan *et al.*, 2023). These challenges need to be remedied to ensure that small-scale agri-food businesses have the full benefits of applying Blockchain technologies. Policymakers should address improving the digital literacy of small-scale agri-food business operators to ensure that these businesses harness the benefits and opportunities technology applications bring, enhancing trust in the supply chain and linking small-scale agri-food businesses to a global value chain.

6.1. Implications for research

This paper makes a contribution by highlighting contemporary framing of the central focus of this work, but also demonstrates that further empirical work needs to be undertaken to better understand how Blockchain can be applied effectively, and the mechanisms to do this is in a low cost way where small-scale farmers and agri-food businesses are not priced out of the market, but have the data they need to remain resilient and to sustain their businesses, communities and minimise environmental impact.

6.2. Implications for practice

This study found some gaps in literature that can be addressed by scholars in the agri-food research domain. While we reported findings that focused on different aspects of Blockchain application in the agri-food business sector in terms of resilience and related benefits such as elimination of systems' boundary and business continuity (Casino *et al.*, 2021), the challenges identified still require research attention. Future studies should consider how to mitigate these challenges especially for small-scale agri-food businesses that are also likely to be affected by cost-related challenges to implementation.

6.3. Limitations and future research directions

Our findings show the wide geographical scope of research in this area and demonstrate the global relevance of the adoption of Blockchain as a resilience-enhancing measure. Yet, the study also reveals a potential limitation in terms of developing country-specific solutions as evidence was not forthcoming in this review. Hence, there are opportunities to consider the application of Blockchain technology for small-scale agri-food businesses that are more accessible, affordable, generalisable, and applicable irrespective of country or commodity context. This review found limited studies in the context of Blockchain in small-scale agri-food businesses. Further empirical studies need to be carried out in the context of Blockchain applications and their role in promoting resilience in small-scale agri-food businesses. Such research can also look at the Blockchain application for resilience in small-scale agri-food businesses from the perspectives of the role of stakeholders, economic and environmental trade-offs, and contextual regulatory and policy implications.

Figures:

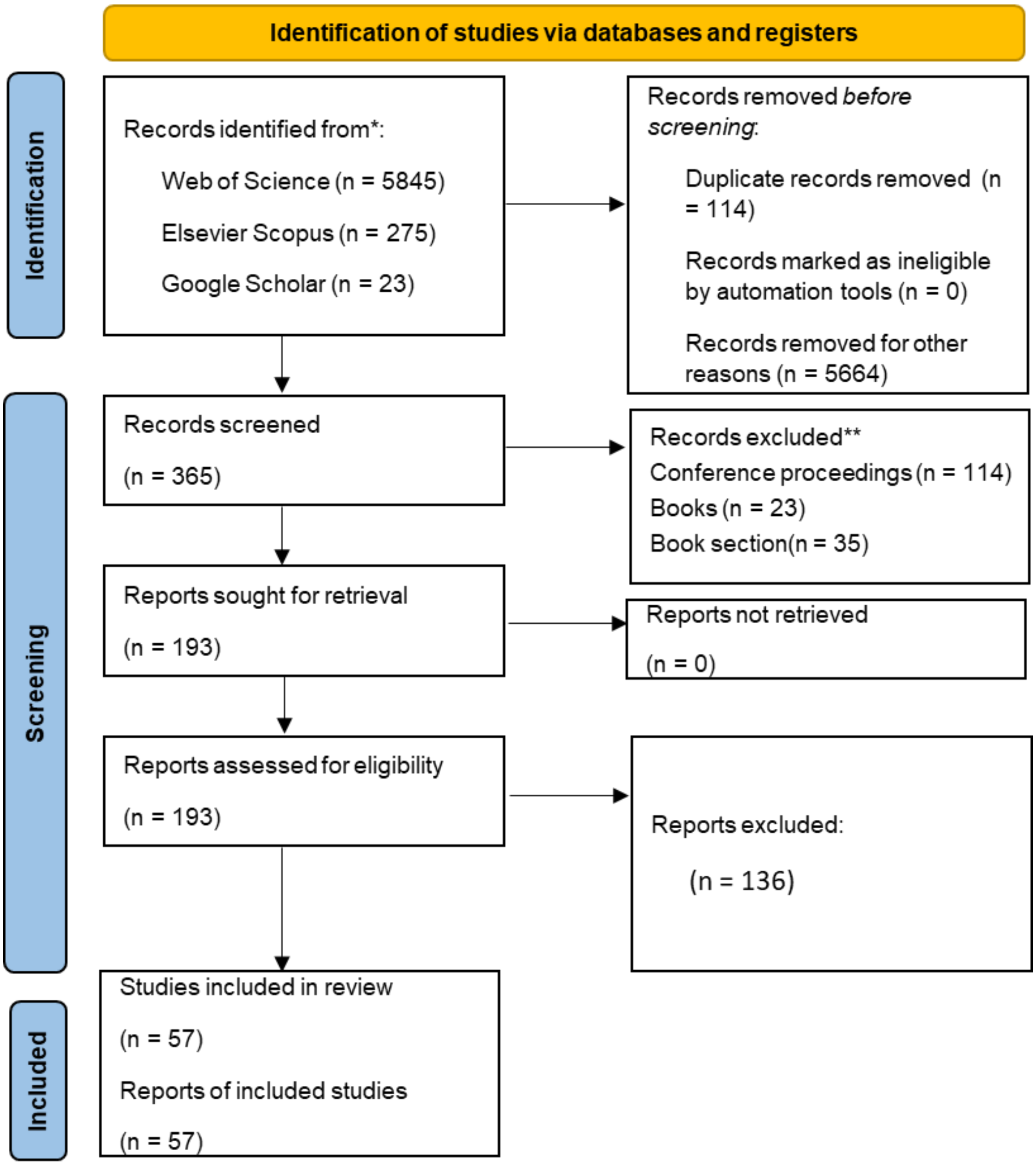

Fig. 1. Preferred reporting items for systematic reviews and meta-analysis (PRISMA) flowchart with the different stages of data screening.
Source: Adapted from Page et al. (2021).

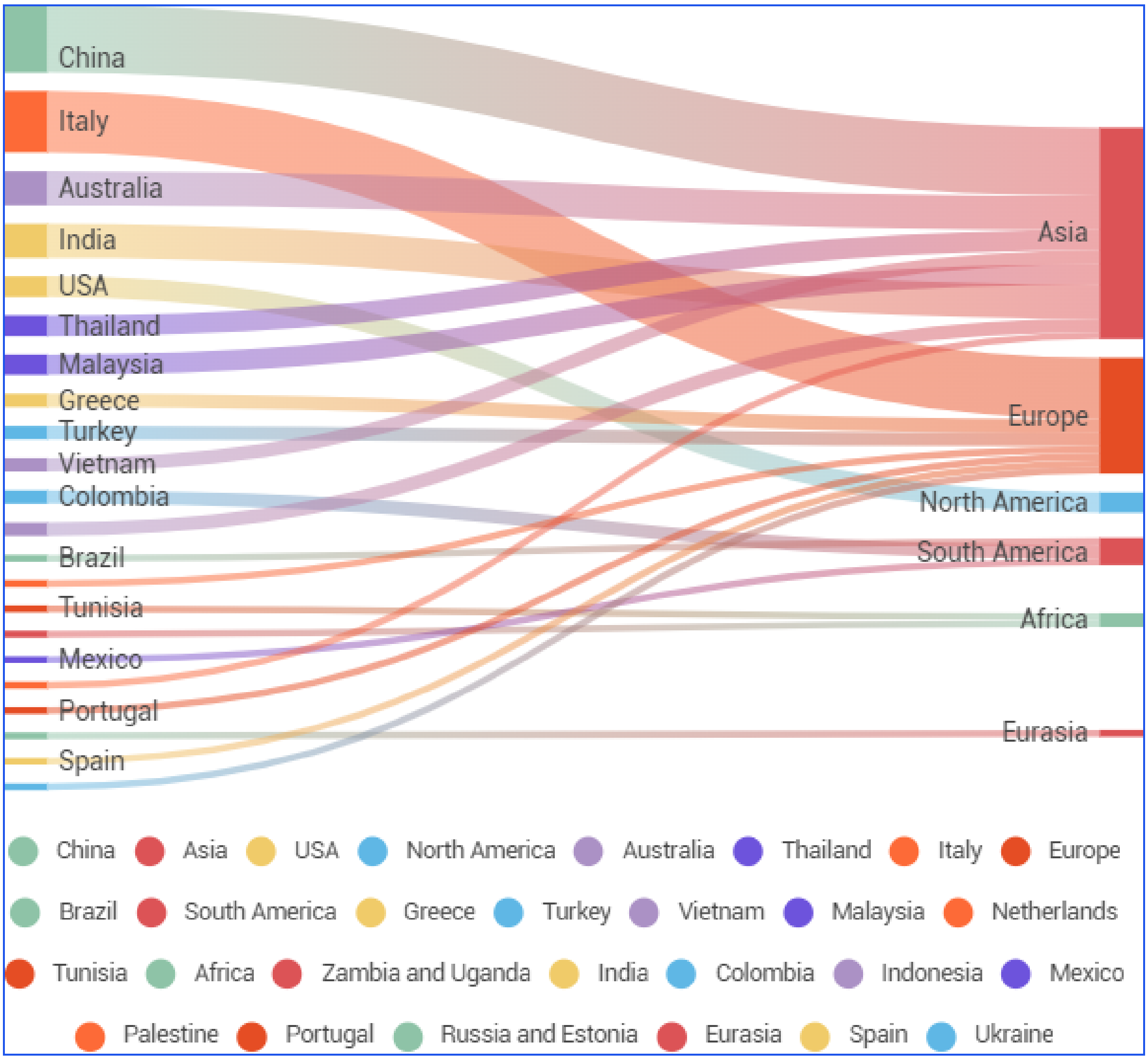

Fig. 2. (n=57): Sankey diagram showing number of occurrences of the countries and their regions as represented in the literature studied.

Source: Authors (differences in frequency of appearance of papers was low).

Tables:

Table 1. Criteria for inclusion and exclusion of articles in this review.

Criteria	Included	Excluded	Justification for criteria application
Publication date	2000 to 2023.	Before 2000.	Available papers from Web of Science, Google Scholar and Elsevier Scopus to have a historical perspective on the resilience management of small-scale farmers.
Language of publication	Papers written in English language	Papers in other languages except English	For readability and researcher' proficiency in English language.
Main publication theme	Papers on supply chain resilience management.	Non- supply chain resilience papers.	To be within the scope of the systematic review.
Article availability	Full paper available	Full paper not available	Paper must be read in full.
Type of article	Peer-reviewed empirical research and book chapters	Conference proceedings, review journal articles, editorials	Increased validity of findings
Scope	Small-scale agri-food business-related papers.	Non-small scale agrifood business related papers.	To remain within the scope of the review.

Source: Authors' computations.

Table 2: Blockchain application in agri-food business sectors in the examined literature.

Country	Supply chain sector	Risk/resilience measures if highlighted in the paper	Aspect of Blockchain application	Paper type (conceptual or research)	Reference
Australia	Beef	Unspecified	Transparency, Trust	Conceptual	(Robb et al., 2020)
Australia	Baby food	Type of technology configuration	Visibility and trust	Research	(Rogerson and Parry, 2020)
Australia	Beef	Unspecified	Transparency	Research	(Cao et al., 2022)
Australia and China	Beef	Unspecified	Traceability, trust.	Research	(Cao et al., 2021)
Australia	Aquaculture	Unspecified	Provenance, traceability.	Research	(Garrard and Fielke, 2020)
Brazil	Grain	Data accuracy and technology availability	Fraud, delay, quality assurance	Research	(Lucena et al., 2018)
China	Rice	Unspecified	Safety and quality	Research	(Peng et al., 2022)
China	Organic food	Use of incentive mechanisms	Traceability	Research	(Ding and Bai, 2022)
China	Fresh products	Risk attitude	Traceability	Conceptual	(Wu et al., 2021)
China	Jujube	Unspecified	Traceability	Conceptual	(Song et al., 2023)
China	Agri-food	Unspecified	Transparency, traceability, security, and sustainability.	Research	(Joo and Han, 2021)
China	Fresh produce	Unspecified	Traceability	Research	(Yi et al., 2022)
China	Agri-food	Unspecified	Transparency, productivity, competitiveness and sustainability	Research	(Fu et al., 2020)
China	Grain and oil	Unspecified	Traceability and trust.	Research	(Zhang et al., 2022)
China	Grain	Unspecified	Food quality, safety and traceability	Research	(Zhang et al., 2020)
China	Fresh food	Risk attitude	Traceability	Research	(Liu et al., 2022)
Colombia	Coffee	Unspecified	Traceability, transparency, and reliability.	Conceptual	(Valencia-Payan et al., 2022)
Colombia and Denmark	Coffee	Unspecified	Transparency, traceability.	Research	(Bager et al., 2022)
Global	Cocoa	Unspecified	Immutability, transparency, visibility, traceability, integration.	Research	(Kayikci et al., 2022)
Greece/ Global	Dairy	Type of technology configuration	Traceability	Research	(Casino et al., 2021)
Greece	Table olives	Unspecified	Traceability	Research	(Kechagias et al., 2023)
India	Grape wine	Supply chain efficiency and quality management	Traceability	Research	(Saurabh and Dey, 2021)
India	Agri-food	Technology implementation	Interfirm trust and transparency, safety, improved visibility.	Research	(Sharma et al., 2023)

India	Agri-food	Unspecified	Traceability, food safety and quality.	Research	(Gupta and Shankar, 2023)
India	Dairy	Unspecified	Transparency, traceability.	Research	(Khanna et al., 2022)
India	Pork	Shared processes and record keeping	Food quality, traceability.	Research	(George et al., 2019)
Indonesia	Halal Poultry	Unspecified	Traceability, transparency.	Research	(Sidarto and Hamka, 2021)
Italy	Agrifood	Unspecified	Traceability/ visibility	Research	(Compagnucci et al., 2022)
Italy	Wine	Unspecified	Traceability and sustainability		(Spadoni et al., 2019)
Italy	Ancient grains pasta (wheat)	Unspecified	Disclosure, traceability, waste, fraud, and abuse.	Research	(Bandinelli et al., 2023)
Italy	Wine	Unspecified	Provenance, quality, consumer trust.	Research	(Silvestri et al., 2023)
Italy	Fish	Unspecified	Sustainability	Conceptual	(Mileti et al., 2023)
Italy	Coffee	Unspecified	Traceability and transparency.	Research	(Gazzola et al., 2023)
Italy	Dairy	Unspecified	Traceability	Research	(Varavallo et al., 2022)
Italy	Wine	Unspecified	Traceability, sustainability and transparency	Research	(Luzzani et al., 2021)
Malaysia	Halal	Unspecified	Traceability	Research	(Hew et al., 2020)
Malaysia	Halal food	Unspecified	Food integrity, safety, and quality.	Research	(Ali et al., 2021)
Malaysia	Halal food	Unspecified	Traceability	Research	(Tan et al., 2022)
Mexico	Avocado	Unspecified	Integrity, traceability, transparency.	Research	(López-Pimentel et al., 2022)
Netherlands	Organic food	Ability to verify data	Traceability, transparency.	Research	(van Hilten et al., 2020)
Palestine	Agri-food	Unspecified	Competitiveness	Research	(Hamdan et al., 2022)
Portugal	Restaurant food delivery	Secured information sharing	Trust	Research	(Tokkozhina et al., 2023)
Russia and Estonia	Food industry	Unspecified	Transparency, efficiency, traceability and standardization	Research	(Dehghani et al., 2022)
Spain	Agri-food	Unspecified	Food control and traceability	Research	(Martínez-Castañeda and Feijoo, 2023)
Thailand	Coffee	Unspecified	Traceability	Research	(Tharatipyakul et al., 2022)
Thailand	Fish	Integrated technology implementation	Food safety, quality, and fraud prevention	Research	(Tsolakis et al., 2021)
Thailand	Fish	Unspecified	Transparency and traceability	Research	(Tsolakis et al., 2023)
Tunisia	Olive oil	Unspecified	Traceability	Research	(Ktari et al., 2022)
Turkey	Dairy	Recording information on quality and hygiene	Traceability, food safety and transparency	Research	(Mangla et al., 2021)
Turkey	Tea	Recording quality and hygiene data	Transparency, traceability, reliability, consensus standards.	Conceptual	(Mangla et al., 2022)
Ukraine	Fish	Unspecified	Transparency, and decentralisation.	Research	(Iermakova et al., 2022)

USA	Food/egg	Reduce risk and cost of food recalls, fraud, and product loss	Traceability and transparency	Research	(Bumblauskas et al., 2020)
USA	Fresh milk	Technology availability	Food safety and quality	Research	(Kasten, 2019)
USA	Coffee	User-friendly technologies availability	Ecological embeddedness	Research	(Trollman et al., 2022)
Vietnam	Cashew	Consistent data recording	Traceability, transparency, and efficiency.	Conceptual	(Chu and Pham, 2022)
Vietnam	Dairy	Unspecified	Food safety and traceability	Research	(Tan and Ngan, 2020)
Zambia and Uganda	Cassava, Sorghum and Dairy	Unspecified	Transparency and accountability	Conceptual	(Lee et al., 2022)

Source: Authors' synthesis.

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