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Blockchain in Supply Chain Management: A Synthesis of Barriers and Enablers for Managers

Huzaifa Kafeel
Warwick Manufacturing Group,
University of Warwick, Coventry, UK.
E-mail: Kafeelhuzaifa@gmail.com

Vikas Kumar
Faculty of Business, Law and Social Sciences,
Birmingham City University, Birmingham, UK.
Department of Management Studies,
Graphic Era Deemed to be University, Dehradun, India.
University of Economics Ho Chi Minh City (UEH),
Ho Chi Minh City, Vietnam.
Corresponding author: vikasnifft@gmail.com

Linh Duong
Bristol Business School,
University of the West of England, Bristol, UK.
E-mail: linh.duong@uwe.ac.uk

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Abstract
Blockchain is an emerging and disruptive technology and has the potential to change how supply chains manage their information. However, Blockchain is accompanied by challenges, such as increased information technology complexity, issues of scalability, incompatibility with existing laws and regulations, and a lack of awareness among organisations and customers. This research conducts a bibliometric analysis based on a sample of 68 papers which address the barriers and enablers of blockchain adoption in supply chain management. A recurring theme in the papers was managers' lack of understanding of Blockchain, which acted as a barrier to adoption. This study proposes a possible explanation by arguing that the academic models used in literature are too obscure from a manager's perspective and that there is a need to synthesise literature into a framework which is easily understood and familiar. Therefore, the barriers and enablers identified in this study were grouped into the robust Political, Economic, Social, Technological, Legal, and Environment (PESTLE) framework. A key finding from this framework was the absence of political barriers or enablers, which is surprising since blockchain adoption challenges the current status quo in multiple ways. Furthermore, the environmental enablers and barriers were scarcely discussed, with little empirical evidence.

Keywords- Blockchain, Supply chain management, Systematic literature review, Bibliometric analysis, PESTLE.

1. Introduction
1.1 Blockchain
Blockchain technology is still in the early stages of development, and there is a general lack of understanding of it (Scott et al., 2017; Waller et al., 2019). A blockchain is "a digitised, decentralised, tamper-proof ledger platform that records and verifies transactions, and cuts out the middlemen" (Vyas et al., 2019). A key takeaway from this definition is that Blockchain is essentially a database, i.e., the primary purpose is to store transactions over a period of time. The difference between a traditional, centralised database and a Blockchain is how this data is stored and secured.

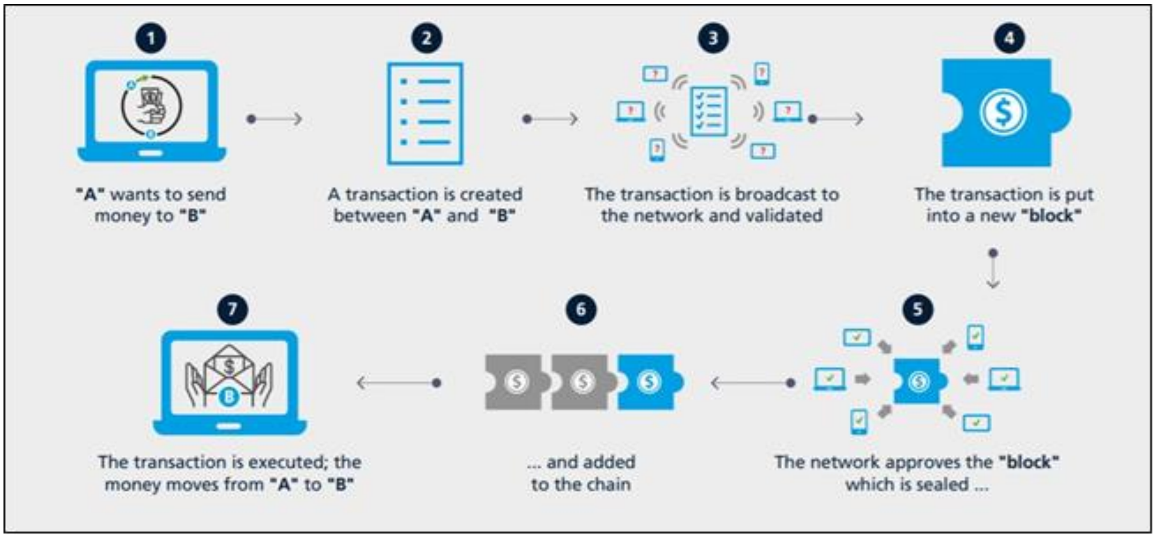

Figure 1. How a generic blockchain transaction works (Accenture, 2018).

Figure 1 shows how a generic blockchain-based transaction works. The network is made up of nodes; each node represents a single participant in the network. Every node participates in the verification of transactions to add new blocks through consensus mechanisms. A block is simply a combination of different transactions which are cryptographically secured using hashes. These blocks are linearly linked to each other in a chain, hence the name blockchain. Each block contains its data, timestamp, hash, and the previous block's hash. New blocks are added using a consensus mechanism, with Proof-of-Work (PoW) and Proof-of-Stake (PoS) being the most popular ones.

1.2 Blockchain in SCM

Blockchain's use was initially explored in the financial sector; however, research into blockchain applications in Supply Chain Management (SCM) has recently become a hot topic (Wamba and Queiroz, 2020). Contemporary supply chains are hyper-connected and increasingly complex, resembling the more chaotic network. Managing supply chain networks simultaneously and efficiently remains a crucial problem in supply chain management (Badenhorst-Weiss et al., 2017). The failure of many businesses can be attributed to the inability to manage the product's movement with its information and transactional flows (Chopra, 2018). Information flow can be viewed as real-time information regarding the product's state and historical information associated with the product. Trackability is the ability to reconcile the physical flow with the real-time information flow. Traceability is the ability to view historical data about the product's handling. When both of these characteristics are adequately managed through an appropriately designed supply chain, it gives rise to visibility.

A key issue faced by supply chain managers is the lack of visibility into their suppliers' processes. The interconnected and dynamic nature of today's supply chains means that firms seldom have information beyond second-tier suppliers (Busse et al., 2017). Consequently, if something goes wrong in the chain, businesses may not find out until it is too late. An excellent example is the KFC chicken shortage in the United Kingdom (UK) in 2018, which occurred after it switched suppliers to DHL (Priday, 2018). The initial reports indicated the cause to be a traffic accident and the use of a single warehouse. However, the underlying reason was eventually discovered to be a lack of visibility in the supplier's network: DHL's software partner had failed to match up the data properly with KFC's system (Vyas et al., 2019). If KFC had had access to this system, the mismatch might have been identified, and the entire incident avoided. This is where permissioned blockchains can create value by ensuring timely access to information. Two primary characteristics are distributed database and transparency, allowing businesses to monitor even their nth-tier supplier's processes, essentially acting as an early warning system. Furthermore, the increased connectivity and visibility could enable firms to recognise new opportunities for optimising the supply chain, thus enhancing collaboration (Williams, 2019).

A recurring problem in modern supply chains is a mismatch between demand and supply, which amplifies demand as a precaution (i.e., the bullwhip effect). One of the most prominent causes of the bullwhip effect is the lack of transparency and trust due to asymmetrical information sharing (Bhattacharya and Bandyopadhyay, 2011). Data on the Blockchain is immutable since altering a block requires updating the entire ledger from that point forward. Furthermore, data on the Blockchain is visible to everyone with access to the network. This creates a single repository of trust, allowing suppliers and retailers to retrieve data easily and with higher trust, potentially reducing the bullwhip effect (van Engelenburg et al., 2018). Additionally, the timely availability of data and ease of retrieval could reduce forecasting horizons by reducing forecasting errors.

Supply chains are essentially built on trust (Sahay, 2003). Increased globalisation and complexity in supply chains have resulted in organisations focusing on their core business and outsourcing the rest (Leavy, 2004). Consequently, the management of these networks shifted towards relationship building and trust. Trust, however, is a two-way street, and many firms believe their counterpart is not living up to their end of the bargain (Sahay, 2003). This distrust manifests in many supply chain problems, from information asymmetry to lack of risk mitigation. As a result, several third-party organisations, such as banks, are needed to ensure trust within the supply chain (Vyas et al., 2019). This, however, increases the cost and complexity of the chain further.

Blockchain, by design, can eliminate the issue of mistrust. Based on computational logic and code, it shifts the nature of trust from subjective humans to objective, open-source technology (Shein, 2019). Of course, trust is still required; however, this trust is in publicly available and verifiable technology as opposed to trust in human relationships, which are subjective and everchanging. Furthermore, since trust is hardcoded into the nature of Blockchain itself, the need for intermediary third parties such as banks is eliminated. This could result in simplification of the supply network as well as offer cost-reduction benefits.

1.3 Research Gaps and Research Objectives

Although the usefulness of Blockchain in supply chain management and the expression of interest from industry leaders, the actual rate of blockchain implementation remains low (Choi et al., 2020). Nevertheless, multiple studies (Danese et al., 2021; Kamble et al., 2021) have explored the adoption of Blockchain in supply chain management.

Danese et al. (2021) conducted twenty semi-structured interviews to investigate the use of Blockchain in wine supply chains to mitigate counterfeiting, concluding that Blockchain is not a standalone solution and should be used in conjunction with other technologies. Kurpjuweit et al. (2021) explored the barriers and opportunities of Blockchain in additive manufacturing. One of the barriers identified was a lack of understanding and awareness of Blockchain. One participant remarks, "[in the company] there will be questions like: 'Blockchain? Can you eat it? What is this?'". A case study on the textile industry in Northern Italy reported similar findings: the management did not fully understand Blockchain, and therefore the services of a consultant were sought (Caldarelli et al., 2021). Similar gaps were seen in the humanitarian supply chain; a focus group conducted by Baharmand et al. (2021) reported a lack of understanding of

Blockchain's requirements, ambiguity regarding the design, and uncertainty concerning potential benefits. Karuppiah et al. (2021) finalised a list of 45 challenges impeding Blockchain's adoption with experts through a fuzzy Delphi study and ranked them using a combination of Decision Making Trial and Evaluation Laboratory (DEMATEL) and Weighted Aggregated Sum Product Assessment (WASPA) methods. After verification utilising a sensitivity analysis, the top-ranked barrier was a lack of understanding of blockchain technology.

The number of studies exploring Blockchain use cases in supply chain management is rising rapidly (Kamble et al., 2021; Wamba and Queiroz, 2020). Despite a growing body of research, the lack of understanding and awareness about Blockchain indicates that knowledge is available but scattered (Rakshit et al., 2022; Wu et al., 2022). Therefore, collecting and synthesising these findings is necessary to provide a holistic picture of the research field. This would assist managers in understanding Blockchain better and enable researchers to identify past methodologies and future research trends.

This study aims to answer the question: What are the current and future trends in research on the barriers and enablers of blockchain adoption in supply chain management? To do so, the research assimilates publications about barriers and enablers of blockchain adoption in SCM by undertaking a systematic literature review (SLR). Furthermore, through a bibliometric analysis, we investigate the current state of research on barriers and enablers of Blockchain in SCM. Finally, we synthesise barriers and enablers of blockchain adoption in SCM into a suitable framework. Findings from this study offer a research agenda for future research in this interesting domain. Furthermore, the PESTLE framework developed in this research helps increase the awareness among organisations about Blockchain.

The remainder of this study is structured as follows. Section 2 discusses the research methodology. Section 3 conducts a bibliometric analysis to identify research clusters. Section 4 synthesises the identified barriers and enablers into a PESTLE framework. Section 5 discusses the key findings from the bibliometric analysis and PESTLE framework. Section 6 concludes the paper by highlighting practical and theoretical implications and limitations.

2. Methodology

2.1 Bibliometric Analysis

In order to analyse the publications collected through the systematic literature review (SLR), a bibliometric analysis is performed. Bibliometric analysis is a commonly used technique for identifying and describing literature patterns through quantitative analysis and statistics (Dereli et al., 2011; Gautam et al., 2020). A number of analytical tools and software packages are available to aid in performing a bibliometric analysis, such as Vosviewer, Pajek, and various packages on R.

All three options were considered initially; however, the final analysis only used the last one. Pajek and Vosviewer are not used because:

- Pajek requires input in the form of a network (.net) file. Some applications can convert a comma-separated file (.cvs) exported from Web of Science into a network (.net) file. However, the author could not find reliable methods of converting from a network (.net) file to a comma-separated values (.csv) file exported from Scopus, which is the database used in the systematic literature review.
- Vosviewer, while easy and intuitive to use, was limited in terms of the analysis options offered, such as the Louvain Communities Analysis.

The bibliometrix package on R, introduced by Aria and Cuccurullo (2017), covers both shortcomings. It is straightforward to read data into the software. Furthermore, in addition to a range of analysis options at the source, author, and document level, bibliometrix allows multiple clustering algorithms to study the intellectual structure of the dataset. Lastly, bibliometrix is accompanied by a shiny application biblioshiny, which vastly improves the interface and user-friendliness by combining "the computational power of R with the interactivity of the modern web" (Bibliometrix, 2017).

2.2 Data Collection

The study follows the guidelines outlined by Okoli (2015). The search was conducted on the SCOPUS database using the advance search function on 2nd August 2021. SCOPUS was preferred over Web of Science because for the same search string, SCOPUS retrieved more publications. Furthermore, the retrieved dataset by SCOPUS encompassed most of the publications retrieved by Web of Science. The search string comprised of three sets keywords for Blockchain, SCM, and Barriers/Enablers. Keywords for Blockchain include Blockchain, bct, block chain, distributed ledger, shared ledger, cryptographic ledger, and smart contract. Keywords for SCM include SCM, supply chain, value chain, and logistics. Keywords for barriers/enablers include barriers, enablers, drivers, inhibitors, and challenges. The initial search string returned 237 papers which were published in English. The research team checked the abstracts and titles of these papers to ensure that they addressed barriers and enablers of Blockchain in supply chain management. This step results in 97 papers. Then, full texts of these papers were read carefully. 72 papers were excluded because they did not clearly discuss barriers and enablers. The final sample includes 68 articles (Figure 2).

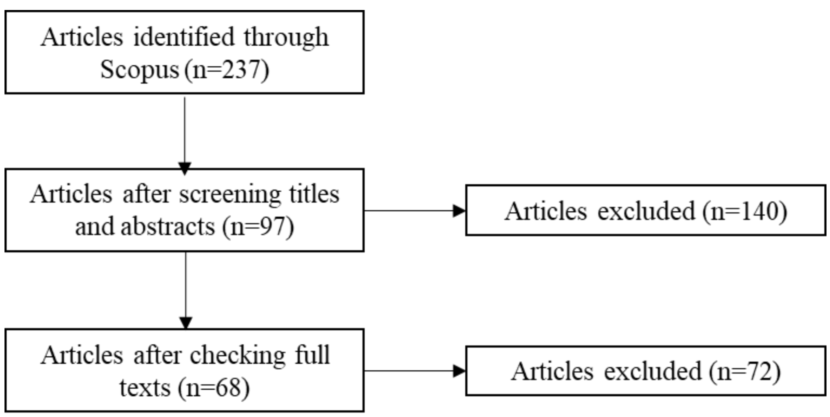

Figure 2. Data collection.

2.3 Descriptive Analysis

The following sections analyse the finalised dataset from three perspectives: year-wise, document-wise, and subject-wise.

2.3.1 Year-Wise

Blockchain publications within the field of supply chain management began in 2013 and rose exponentially after 2016 (Wamba and Queiroz, 2020).

The final sample of 68 papers agrees with this rising publication trend (Figure 3). Most of the papers (53%) were published in 2021, and the earliest paper in this sample is from 2018. This indicates that while blockchain publications in supply chain management gained momentum around 2016, there was no significant discussion around the barriers and enablers to adoption until a few years later.

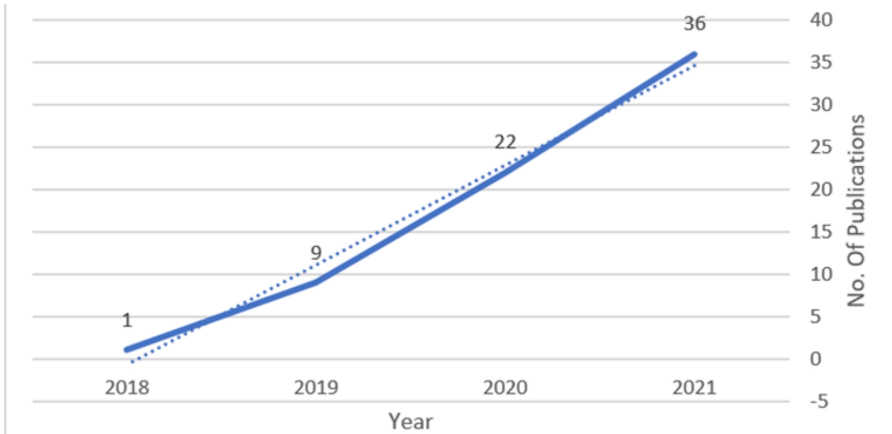

Figure 3. Sample analysis by years.

2.3.2 Document-Wise

Figure 4 shows that the final sample consisted primarily of peer-reviewed journal articles (49) and conference papers (16), followed by reviews (2) and notes (1). Furthermore, 63% of the journal articles and 44% of the conference papers collected and analysed primary data on barriers and enablers through surveys, questionnaires, interviews, and case studies. This supports the need for a synthesising study such as this one.

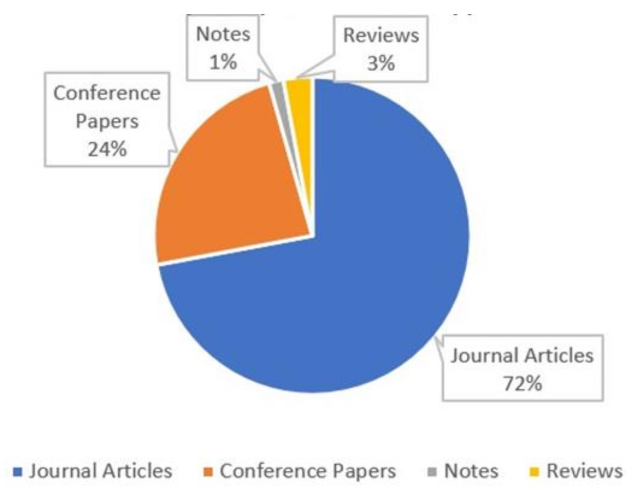

Figure 4. Sample analysis by document type.

2.3.3 Subject-Wise

Papers in the final sample were categorised into 11 distinct areas based on their primary focus. 32% of the papers addressed blockchain barriers and enablers in SCM generally, whereas 25% of the papers specifically focused on food supply chains. Within the food supply chain, wine supply chains were noticeably popular (Danese et al., 2021).

Figure 5 shows that food supply chains are the largest most significantrea of papers discussing the barriers and enablers. It is worth mentioning that this SLR captures six other literature reviews and synthesises their findings along with other papers.

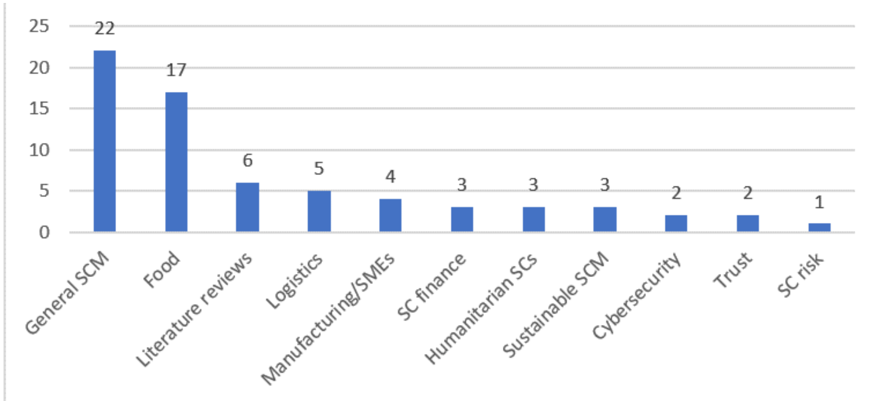

Figure 5. Sample analysis by subject type.

3. Bibliometric Analysis Results

3.1 Source Level Analysis

The source-level analysis is done using Biblioshiny for the bibliometrix package in RStudio. Bradford's law of scattering is used to create source clusters by grouping publications into three zones based on the number of citations, importance, and relevance (Nash-Stewart et al., 2012). Zone 1 contains the most frequently cited sources, followed by moderately cited sources in zone 2 and rarely cited sources in zone 3. The law states that zone 1 sources will be of the most interest to researchers, whereas zone 3 will be of negligible importance.

Figure 6 shows zone 1 clustering using Bradford's law. A total of 9 out of 54 journals are clustered into zone 1. International Journal of Production Research and Journal of Business Logistics are the top two journals, followed by seven others in zone 1.

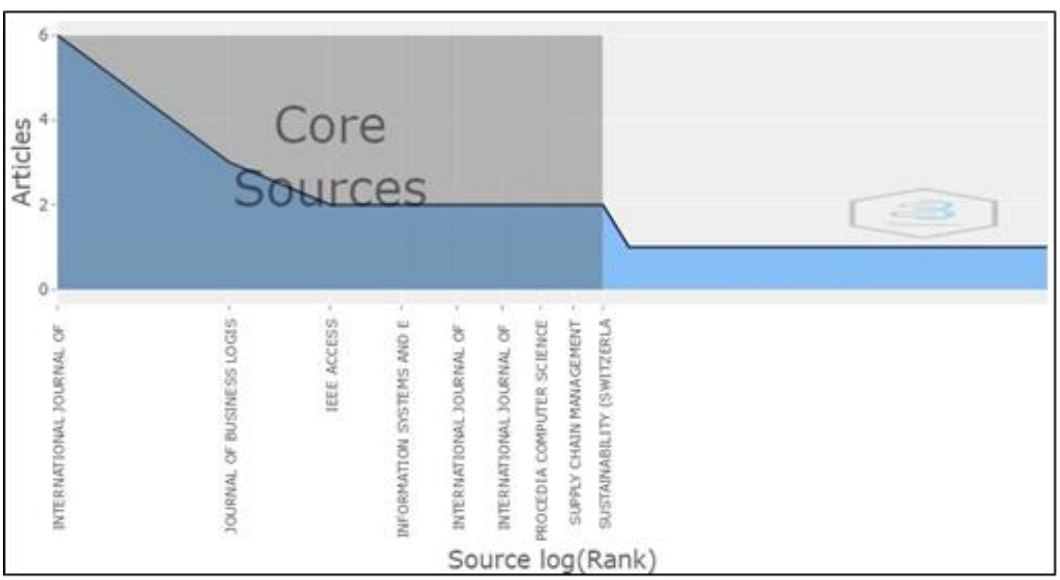

Figure 6. Source clustering using Bradford's Law.

The top five journals in zone 1 are further analysed using three scholar indices: h-index, g-index, and m-index (Table 1).

h-index: The h-index is defined as "the number of papers with citation number higher or equal to h" (Hirsch, 2005). Essentially, a higher h-index indicates that a journal has a high number of publications with an equally high number of citations.

g-index: The g-index is a variation of the h-index, proposed by Egghe (2006). The h-index is insensitive to papers with very high and very low citations. Egghe (2006) argued that the former is a weakness such that once papers had been included in the top h papers, they do not affect the h- index any longer, even if their citations rise exponentially. Therefore, the g-index was proposed and defined as "the (unique) largest number such that the top g articles received (together) at least g2 citations".

m-index: The m-index is another variation of the h-index and is simply the h-index divided by the number of years since its first publication (Bornmann et al., 2008). This is useful for normalising time periods when comparing two journals of varying ages.

Table 1. shows the local h-, g-, and m-indices of the top 5 journals in zone 1.

Journal	h-index	g-index	m-index	Total Citations	Number of Publications	PY start
International Journal of Production Research	4	6	1.33	568	6	2019
Journal of Business Logistics	2	3	2.00	33	3	2021
IEEE Access	2	2	1.00	19	2	2020
Information Systems and E-Business Management	1	1	0.50	16	1	2020
International Journal of Information Management	2	2	0.67	310	2	2019

These five journals comprise 9.25% of the total sources but contribute 20.59% of the total publications. Interestingly, while the International Journal of Production Research has a higher count in nearly all metrics, the Journal of Business Logistics has a higher m-index. It has the same m-index as its h-index. This is because all three publications from this journal were published in 2021, whereas the six publications in the International Journal of Production Research are spread over three years. This indicates that the Journal of Business Logistics could be a future hotspot for Blockchain in SCM publications focusing on barriers and enablers. The rising and falling interest can be seen in Figure 7.

The interaction of these journals with countries and keywords can be visualised using a three-field plot. Three field plots are helpful for simultaneously comparing three elements of a publication. In Figure 8 a three-field plot is used to map sources to countries and keywords. The height of a rectangle is proportional to the number of papers associated with it, while the width of the grey links is proportional to the share of the papers associarelated with. Therefore, the taller a rectangle is, the more its contribution is. Similarly, the more comprehensive a link is, the stronger the affiliation between the two factors.

China, the USA, and the UK are the top three most active countries in the discussion around barriers and enablers of BCT in SCM. The work of researchers in the USA was predominantly published in the *International Journal of Production Research* and *Business Logistics*, focusing on strategy and managerial aspects. On the other hand, China is publishing more in *Information Systems* and *e-Business Management*, which focuses on computer science and information systems. This could indicate an interesting research bias where one country is exploring the managerial side of blockchain-enabled supply chains. In contrast, the other is leaning towards the technological aspect of it.

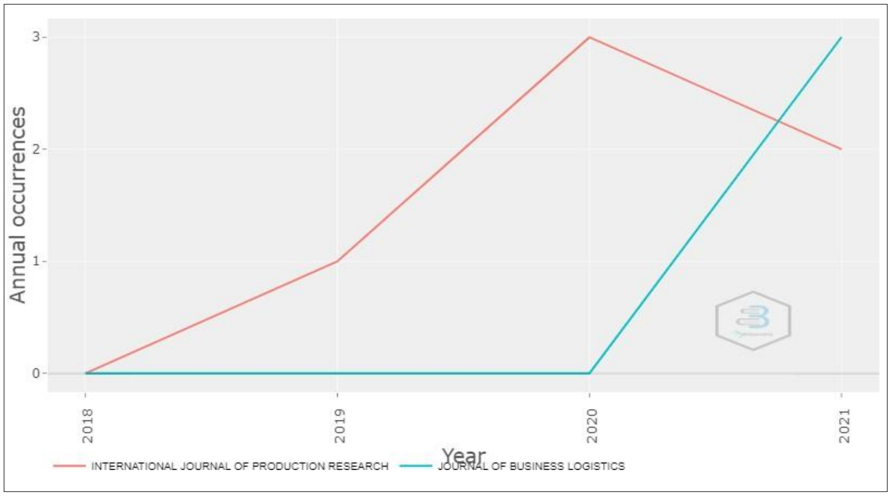

Figure 7. Source growth by years.

All three of these journals are linked strongly to the keywords "blockchain" and "supply chain", which is expected since it is the main theme. However, the *International Journal of Production Research* links strongly to "barriers" as well, while the *Journal of Business Logistics* links to "technology adoption". Additionally, the rectangle's height for "barriers" is four times larger than for "technology adoption". This indicates that research is more focused on the barriers rather than the enablers, with the *International Journal of Production Research* addressing the former and the *Journal of Business Logistics* focusing on the latter.

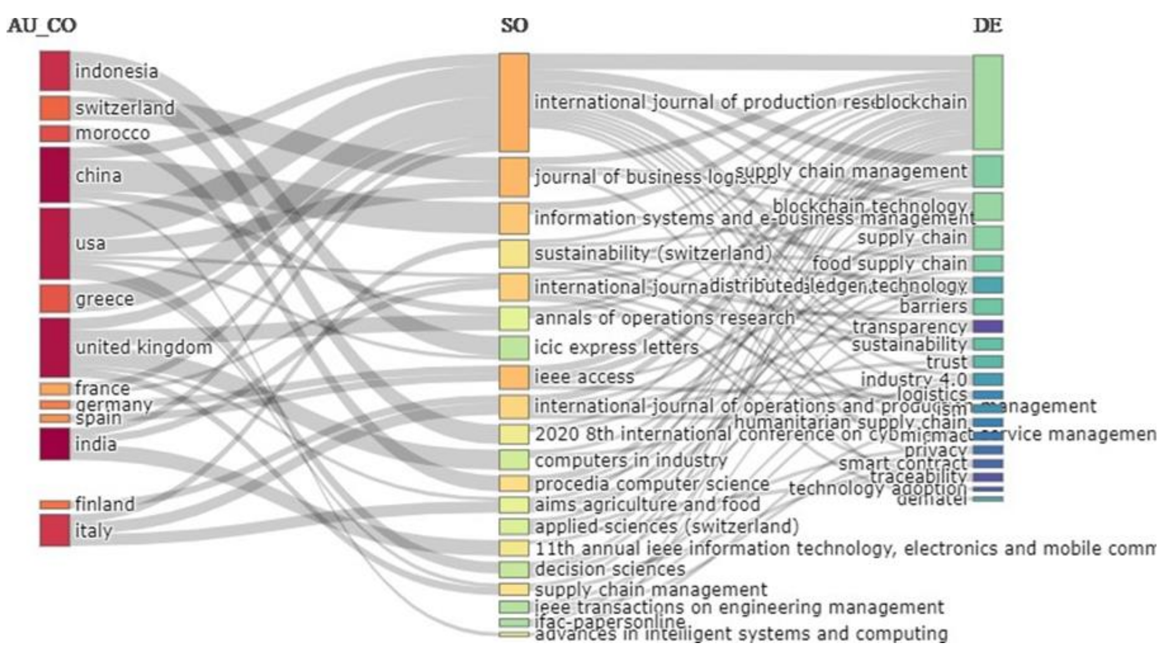

Figure 8. Three fields plot (country, source, keywords).

3.2 Network Analysis: Keyword Co-occurrence

The network-level analysis is performed using a Louvain-based co-occurrence network. Keywords Plus are chosen as the analysis parameter. Unlike author keywords, Keywords Plus use “additional search terms extracted from the titles of articles cited by authors in their bibliographies and footnotes” (Garfield, 1990). This makes Keywords Plus a more broadly descriptive metric, often covering most of the author keywords (Zhang et al., 2015).

A co-occurrence network built using Keywords Plus “draws upon the assumption that a paper's keywords constitute an adequate description of its content”, and many co-occurrences of the same keyword pairs indicate a research theme (Ding et al., 2001). Figure 9 shows the co-occurrence network created using the biblioshiny app for bibliometrix in Rstudio.

The network is divided into five clusters based on the Louvain Communities Detection Algorithm. The Louvain algorithm groups nodes into communities based on inter-node linkages versus intra-node linkage (Blondel et al., 2008) and is an efficient algorithm to group a network of keywords into smaller communities or clusters (Etemadi et al., 2021). These clusters, shown in different colours, represent a particular research theme in the literature. The five detected clusters are described in Table 2.

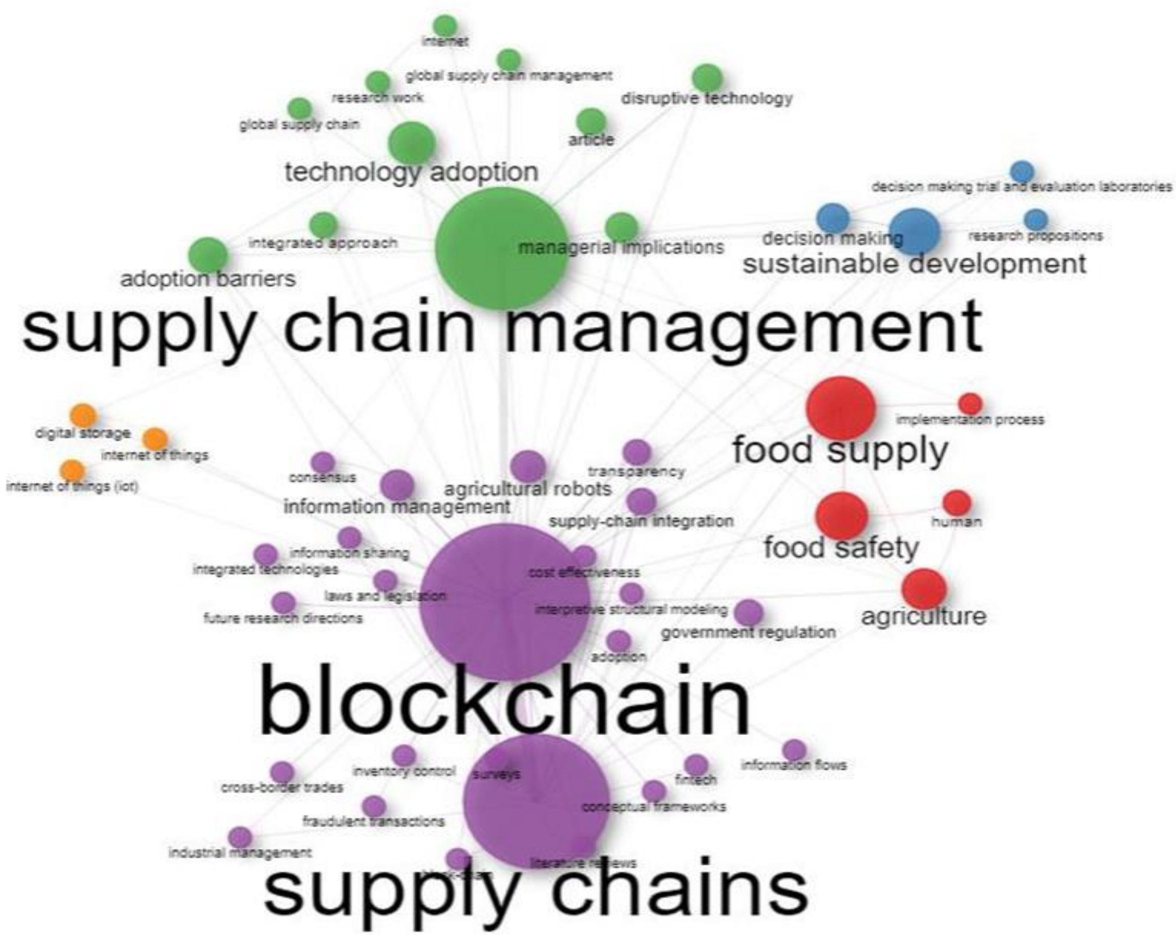

Figure 9. Co-occurrence network of keywords using Louvain communities detection algorithm.

Table 2. Clusters obtained through the Louvain algorithm.

Cluster Number	Cluster Theme
1	Blockchain-enabled supply chains for information management and the role of laws and legislation
2	Barriers, enablers, and implications of blockchain adoption in global supply chain management
3	Blockchain-enabled food supply chains
4	Adoption of Blockchain in SCM using trial and evaluation: Use cases from the real world
5	Blockchain integration with IoT: Opportunities and limitations

3.2.1 Cluster #1: Information Management and the Role of Regulation

The first cluster primarily focuses on Blockchain's role in information sharing within supply chain management. Papers included in this cluster use both primary and secondary data. Government regulation, laws, and legislation as barriers to adoption are a recurring theme.

Blockchain is primarily an information technology and stands to transform the way information is shared drastically within supply chains (Saberi et al., 2018). The timely availability of information to different stakeholders in a supply chain is paramount and ultimately determines the quality of collaboration. Li and Wang (2021) argue that other stakeholders may not detect changes in data by one stakeholder in time. This problem is exacerbated with the advent of Big Data, such that the amount of data being processed, i.e., the volume of data, has risen exponentially. Volume is one of the three Vs of Big Data, initially coined by Doug Laney at Gartner (Gartner Inc, 2013), with velocity and variety being the other two. The three Vs essentially mean that supply chains must deal with an ever-increasing volume of data flowing at ever-increasing velocities from various sources. Therefore, it is important to have systems that can cope with the evolving nature of data and enable timely information sharing between supply chain partners.

However, Blockchain is by no means a silver bullet for information sharing. Trust in the technology itself is a major barrier (Wamba and Queiroz, 2020). In addition, organisations may view information as an asset and competitive advantage and, therefore, would be hesitant to share it on a blockchain (Saberi et al., 2018), despite private and permissioned blockchains. One explanation is that most organisations and managers still do not fully understand blockchain technology (Mathivathanan et al., 2021).

A recurring theme in this cluster is the lack of standardised frameworks for governing blockchain collaborations. Baharmand and Comes (2019) mention three frameworks, i.e., social, legal, and regulatory, and argue that they are being developed relatively slowly. This uncertainty in future regulations could cause unintended consequences, resulting in organisations' hesitancy toward Blockchain adoption (Mathivathanan et al., 2021). For example, one of Blockchain's primary characteristics, immutability, is mentioned both as an enabler and a barrier (Saberi et al., 2018). This is because specific data protection regulations require personal data to be removed after a period of time, such as GDPR's "Right to be forgotten", which is counterintuitive to Blockchain's immutability (Jongerius, 2019). Furthermore, the uncertainty of future legislation is exacerbated by the adverse policies implemented by some governments regarding cryptocurrencies in general and Bitcoin in particular (Saberi et al., 2018), creating negative precedence for blockchain adoption.

There are, of course, exceptions to this general tendency. Caldarelli et al. (2021) conducted an exploratory study on the adoption of blockchain technology in the supply chain of Carrera Group, the textile industry in Northern Italy. They found that the lack of government regulations was not perceived as a limitation by the company, as the CEO was not averse to taking risks. The same results were obtained separately by Falcone et al. (2020) in a survey of supply chain and information technology managers, concluding that risk does not negatively mediate the managers' willingness to use blockchain technology.

3.2.2 Cluster #2: Barriers, Enablers, and Managerial Implications in Global SCM

The second cluster addresses barriers, enablers, and managerial implications of blockchain adoption in global supply chains. The Technology-Organisation-Environment (TOE) framework is frequently used, often combined with other techniques such as DEMATEL (Kouhizadeh et al., 2021) or TAM-DOI (Bhardwaj et al., 2021).

Improved visibility and traceability are the most identified enablers. Questionnaire results obtained by Baharmand et al. (2021) consider cross-sector collaboration as an important driver of BCT adoption, while another paper concluded that traceability-enabled collaborations were the primary incentive (Jardim et al., 2021). Even though enhanced product traceability results in a better perception of quality by the customers (Li et al., 2020), the pressure from customers is less influential for companies to consider adopting Blockchain in their supply chains; instead, their focus is on improving SC visibility and traceability (van Hoek, 2019). This indicates cost benefits, such as reducing the bullwhip effect (Jardim et al., 2021) and improved flexibility due to better inter-vendor visibility (Lai et al., 2021), the primary motivators of blockchain adoption in SCM. Blockchain-enabled supply chains could also help reduce or even eliminate the problem of counterfeit products (Kurpjuweit et al., 2021) and improve cost efficiency by using smart contracts, effectively eliminating administrative delays due to manual/semi-automated paperwork (Baharmand et al., 2021).

Compared to enablers and drivers, the barriers to adoption are discussed more often. Blockchain is a relatively new technology at the Proof of Concept (PoC) stage (Valle and Oliver, 2020). The immaturity of this technology is frequently cited as a primary barrier to adoption (Kouhizadeh et al., 2021), which serves as a catalyst for several other technological barriers such as interoperability and compatibility. Interoperability is the lack of congruency between different blockchain systems (Kurpjuweit et al., 2021), whereas compatibility refers to the difficulties in integrating Blockchain with legacy IT systems (Sternberg et al., 2020). Both barriers can be linked to a lack of standardisation and the absence of a globally agreed-upon framework for blockchain development and integration (Chang et al., 2019). International efforts are underway, such as the formation of a technical committee (ISO/TC 307) by the International Organisation for Standardisation (ISO, 2016); however, lack of standardisation remains a barrier (van Hoek, 2019).

Lack of stakeholder willingness to participate is also a key barrier to adoption (Liu et al., 2021). This is especially more challenging for global supply chains, which have many stakeholders dispersed all over the world. Differences in cultures can impede blockchain adoption (Kouhizadeh et al., 2021). A lack of trust between supply chain partners can be seen because of this cultural difference, which translates to a lack of cooperation. This is further aggravated by the high cost of R&D, implementation, and maintenance of the blockchain infrastructure (Karuppiah et al., 2021). The problem manifests itself on an intra-organisational scale as well, in the form of a lack of management support (Boutkhoum et al., 2021), which is often due to the lack of a business case (Kurpjuweit et al., 2021) and uncertainty of ROI (van Hoek, 2019) for blockchain adoption at this point. Vafadarnikjoo et al. (2021) argue that the lack of managerial support could be linked to Hofstede's cultural dimensions, i.e., uncertainty avoidance. This emphasises the need for viewing the barriers to blockchain adoption from multiple lenses.

3.2.3 Cluster #3: BCT-Enabled Food Supply Chains

Food supply chains were the main topic area in the final sample set, with 25% of all papers focused on them. Therefore, it is no surprise that the Louvain algorithm detected an entire cluster based on blockchain-enabled food supply chains. Supply chain traceability and visibility are generally relevant for industries, but they are essential for food supply chains. Quality lapses at any stage of the chain can have serious health risks for customers while also opening the suppliers to litigation risks (Barykin et al., 2020; Nurgazina et al., 2021). Foodborne diseases directly result from the inefficiency of current supply chains and can lead to outbreaks (Osei et al., 2021) and pandemics, such as the recent COVID-19 outbreak. Origin visibility is especially crucial in halal food supply chains, which have an added layer of regulation in the form of halal certifications (Ali et al., 2021). The immutability of Blockchain can serve as a protection against tampering with halal certificates and mitigating fraudulent production.

Combined with other IoT technologies, Blockchain can be used for anti-counterfeiting measures in niche industries, such as the wine supply chain (Saurabh and Dey, 2020). Customers and regulatory authorities are becoming increasingly concerned not only about the quality and safety of food products but also about the social and environmental effects of the food industry itself (Vu et al., 2021). The rising call for traceability is a primary driver for blockchain adoption in food supply chains. Customers are prepared to pay a premium for blockchain-enabled products if it means the assurance of quality (Osei et al., 2021).

3.2.4 Cluster #4: Trial and Evaluation Use-cases

The fourth cluster groups together pilot studies and use cases of blockchain adoption in supply chains. The smaller node sizes of the cluster indicate the scarcity of real-world implementations. Blockchain's benefits become noticeable once a critical mass of stakeholders adopts the technology (Sternberg et al., 2020), which is an expensive and complex undertaking. At the moment, Blockchain is being studied in small pilot projects to understand the opportunities and challenges better.

Baharmand et al. (2021) studied one of the first pilot cases in Humanitarian Supply Chains, wherein a blockchain-based system tracked a sample shipment from a warehouse in Pakistan to its destination in Dubai through multiple logistics service providers. They found that "downstream integration", the lowest-ranked barrier in the focus group, was one of the top four challenges experienced during the pilot. This was a valuable insight into how complex blockchain integration can be, even on a small scale. Similarly, Sternberg et al. (2020) found that the legacy systems which would read/write onto the Blockchain were challenging to integrate and hypothesised that the absence of industry standards could be a reason. Additionally, the lack of automated data entry meant increased manual workload, leading to decreased operational efficiency.

Very few initiatives have moved beyond the pilot stage at scale. Perhaps the most well-known is TradeLens, a joint venture between IBM and the shipping giant Maersk, which created a consortium for different supply chain partners to securely share information and access real-time shipment data, reducing the transit time by 40% (IBM Newsroom, 2018). Chang et al. (2019) mention similar examples in the transportation industry (The BiTA consortium), food supply chains (initiatives by Carrefour as well as the Walmart/IBM joint venture) and pharmaceutical supply chains (The MediLedger Project). Interestingly, these initiatives, which moved beyond the pilot stage, had one thing in common: they use automated data entry to read/write onto the Blockchain using one or more IoT technologies.

3.2.5 Cluster #5: Blockchain Integration with IoT – Opportunities and Limitations

The fifth and smallest cluster explores the benefits of blockchain integration with IoT for supply chain management and discusses the current limitations. The role of IoT technologies in improving blockchain systems has been discussed above; however, this cluster discusses the advantages and limitations of using Blockchain to improve current IoT applications. The small size of this cluster is understandable since it places IoT at the centre of discussion rather than Blockchain, and the former was not a part of the search strings in the SLR.

Various IoT technologies have been used to increase traceability in supply chains using sensors to track product data (Al-Rakhami and Al-Mashari, 2021). This data is traditionally stored on a centralised cloud database (Valle and Oliver, 2020), which has certain disadvantages, as outlined by Jabbar et al. (2020):

- Lack of traceability,
- Risk of security threats such as a single-node attack, and,
- Risk of data tampering due to lack of immutability characteristics.

Blockchain, by design, solves all three of these concerns. Firstly, since every block contains its timestamp plus the previous block's hash value, transactions can easily be traced to the source of interest (Al-Farsi et al., 2021). Secondly, new blocks are added according to a pre-defined consensus mechanism. A copy of the new chain is stored on all nodes, which renders a single-node attack redundant (Etemadiet al., 2021). Lastly, because each block contains the hash value of the previous one and each node has an identical copy of the Blockchain, manipulating data in a single block requires changing all the subsequent blocks plus having control of at least 51% of all blocks in a network, which is a nearly impossible task (Al-Farsi et al., 2021).

The traceability, security, and immutability features of Blockchain also have downsides. Data storage in the form of new block creation enables traceability but also requires additional processes compared to a traditional, centralised database, which results in higher consumption of time and energy (Al-Farsi et al., 2021). The security characteristics of Blockchain are also not entirely risk-free either, as is evident by various instances of hacking of the bitcoin exchange Mt. Gox in 2011 and 2014, with the latter resulting in a theft of bitcoin worth $450M (Yadav et al., 2020). Furthermore, while the immutability of Blockchain can assure data quality on the chain, it can also become a nuisance if the data is entered incorrectly (Jabbar et al., 2020). Since Blockchain cannot determine the veracity of data input, it is important to have a mediatory layer of AI or neural networks to assess data quality before it is added to the chain (Danese et al., 2021). This again emphasises the need to use Blockchain in combination with other technologies. Blockchain integration into existing IoT systems can be seen as a shift from a centralised cloud-based storage mechanism to a decentralised, peer-to-peer storage network with better traceability, security, and immutability.

4. Framework for Barriers and Enablers

The final set of 68 papers obtained in the SLR was used to extract barriers and enablers. These were first grouped into similar themes by the author and subsequently placed into a PESTLE framework. PESTLE is an acronym for Political, Economic, Socio-cultural, Technological, Legal, and Environmental and is frequently used to examine external factors to a firm or organisation (Britton, 2018). The PESTLE framework discussed the barriers to adopting Blockchain in the creative economy. The closest application of PESTLE for studying the barriers and enablers of Blockchain in a supply-chain context was undertaken by Zhou et al. (2020). The study, however, was limited only to the maritime industry in Singapore. Furthermore, this study used primary data, making it an exploratory research rather than a synthesising one. The final PESTLE framework is shown in Figure 10.

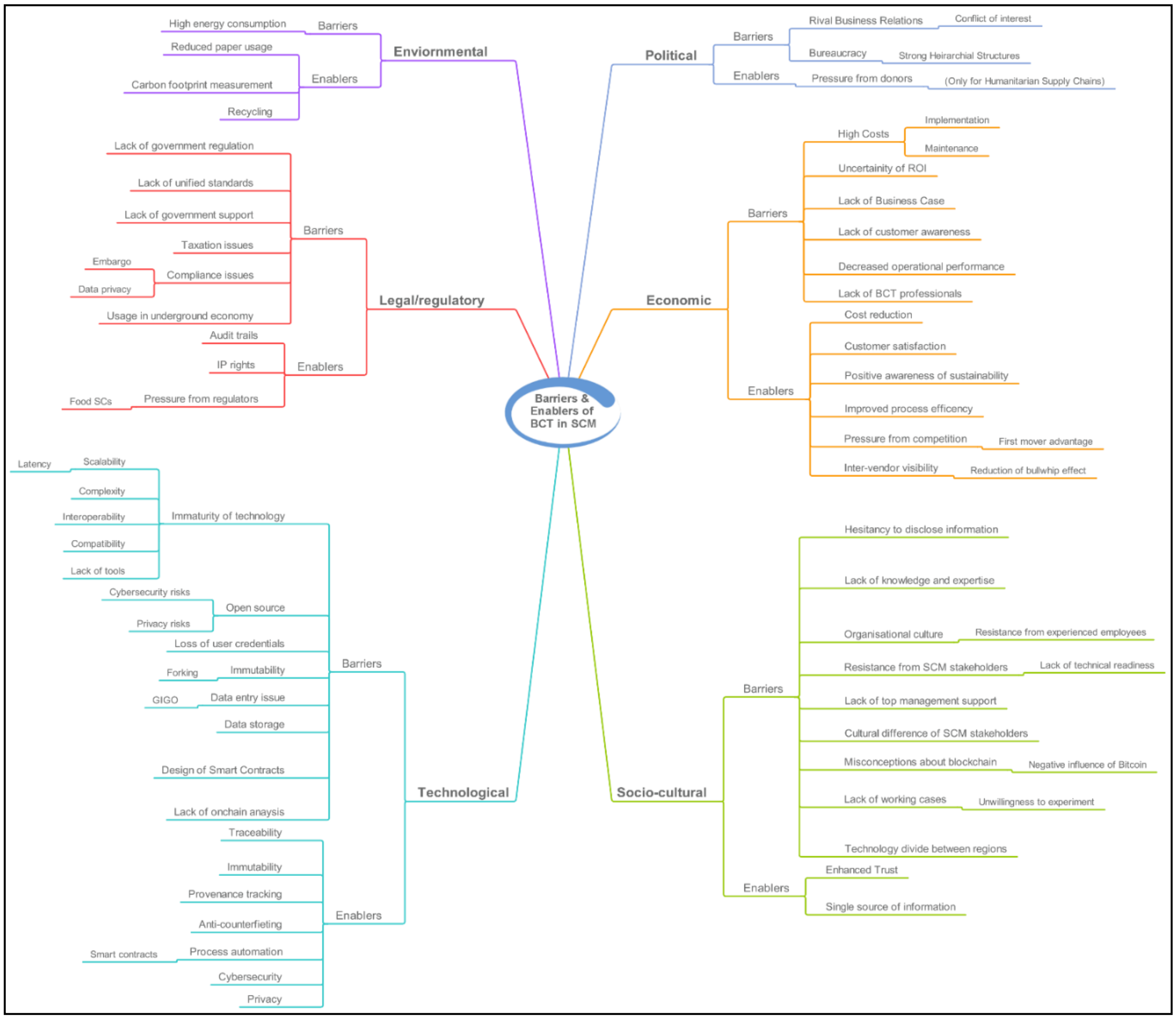

Figure 10. PESTLE framework of barriers and enablers of BCT in SCM.

4.1 Political

Barriers and enablers related to inter- and intra-organisation politics are scarcely present in the literature, which indicates a potential research direction. A case study on a blockchain pilot found that blockchain adoption was hindered because stakeholders were part of multiple supply chains, with no inclination to make disproportionate efforts toward any single supply chain (Sternberg et al., 2020). Kurpjuweit et al. (2021) note that the requirements of one supply chain could be contradictory to another. This is especially relevant when one firm is a supplier for two competing firms. The two competing firms may have different blockchain platforms; in such a case, which one the supplier chooses to comply with remains an inter-organisational issue that can only be solved once a unified standard for blockchain development is agreed upon.

Another barrier to blockchain adoption is its implication for traditional, bureaucratic organisation structures. With its intrinsic properties of transparency and decentralisation, the idea of Blockchain poses a threat to the status quo, and the possibility of a loss of power by the upper management negatively affects the adoption of this technology (Sabbagh, 2021).

The only political enabler appeared in a focus group conducted on Humanitarian Supply Chains (HSCs), which identified “pressure from donors” to be a potential driver for blockchain adoption to increase visibility (Baharmand et al., 2021). It should be mentioned, however, that “pressure from donors” was the lowest-ranked enabler, which indicates that external pressure from funding sources is a weak enabler at best.

4.2 Economic

The most frequently discussed economic barrier is the high cost associated with blockchain technology, including implementation and maintenance costs. Implementation costs are high because Blockchain is a decentralised database; successful implementation requires every supply chain member to be digitalised (Chen et al., 2020). This is a significant challenge in food supply chains, where many stakeholders still use manual pen-and-paper processes (Zhao et al., 2019). Furthermore, responses to the Delphi study by Kurpjuweit et al. (2021) revealed a high demand for blockchain developers, especially those that can code smart contracts. Acquiring the human resource necessary for blockchain implementation drives up the initial cost. This is further compounded by the maintenance costs associated with maintaining the network and the high energy requirements needed for adding blocks to the Blockchain (Karuppiah et al., 2021), also known as the gas cost (Ahmad et al., 2021). Therefore, it is no surprise that early adopters have been large enterprises which can bear the costs in exchange for long-term rewards. However, blockchain adoption remains low since most small and medium enterprises cannot justify such an investment (Vu et al., 2021).

At the same time, a frequently discussed enabler is the potential of Blockchain for reducing costs. This is done in several ways, such as removing the third party and intermediaries from transactions (Tayal et al., 2020), improving time-and-cost efficiency, and reducing settlement times by automating the process through smart contracts (Kamble et al., 2019). Furthermore, implementation costs can also be reduced through economies of scale by adopting the solution as a group or consortia rather than a standalone solution (Vu et al., 2021). This duality of costs as both enablers and barriers creates uncertainties about return-on-investment (ROI) and adoption benefits (Mathivathanan et al., 2021). Somewhat related to this is that Blockchain is expected to improve process efficiency through digitalisation and streamline the flow of information (Kurpjuweit et al., 2021). It can also enhance inter-vendor visibility, reducing the bullwhip effect (Lai et al., 2021). However, pilot implementations have found contradictory results. For example, Blockchain technology improves time efficiency in humanitarian applications (Baharmand et al., 2021). In contrast, it increased administrative pressures and reduced process efficiency in another (Sternberg et al., 2020). The key difference was that the former had a higher level of automation, whereas the latter struggled with manual scanning. Improving upon the latter would require investments in automation, which would further increase the costs discussed previously.

These barriers and paradoxical enablers bring the business case and suitability of Blockchain into question, which differs case-to-case basis. For example, the halal food supply chain depends highly on halal certifications, which are already visible and transparent; adopting them adds no value (Ali et al., 2021). At the same time, pressure from consumers becoming more concerned about the origin of their food products can act as a driver for adopting Blockchain (Vu et al., 2021). One would expect the same trend in sustainable supply chain management, with Blockchain enabling the organisation to share information regarding sustainable and ethical practices with the customer (Sternberg et al., 2020). However, Liu et al. (2021) report the opposite: customers are unaware of green certification systems and disinterested in sustainable practices. Despite these market and economic uncertainties, pressure from competitors can act as a severe enabler (van Hoek, 2019), as was the case with Walmart and Carrefour (Vu et al., 2021). Early adoption could lead to a first-mover advantage but could also become a risk if managed poorly (Valle and Oliver, 2020).

4.3 Socio-cultural

One of the biggest arguments in favour of Blockchain is the creation of trust between supply chain partners by providing a verified, transparent, and immutable source of information (Batwa and Norrman, 2021). However, creating this singular source requires companies to disclose information on an open platform. Since companies view information as an asset and a source of competitive advantage, the lack of trust becomes a barrier to adoption (Liu et al., 2021). There is a fear that the companies' data will be used against them (Falcone et al., 2020), a real-world example of which is the mishandling of a supplier's information, resulting in the creation of competitors in the market (Ali et al., 2021). This gives rise to yet another paradox: enhancing trust using Blockchain requires stakeholders to invest in terms of finances as well as information, which is only viable if trust already exists between the stakeholders (Sternberg et al., 2020).

Organisational culture also plays a significant role in determining blockchain adoption. Most companies are more risk-averse, and a lack of support from top management is often cited as a barrier to technology adoption (Kouhizadeh et al., 2021). If the end goal is to improve supply chain efficiency, technology alone is not enough; proper organisational change programmes are necessary (Vafadarnikjoo et al., 2021). This is especially relevant in the case of Blockchain, a decentralised technology which requires legacy systems to be extensively altered or replaced. These changes in the system and, consequently, the organisational structure can lead to resistance from the top management and the employees themselves (Liu et al., 2021). This resistance to change also stems from the lack of knowledge and awareness (Sahebi et al., 2020). It could further be exacerbated by the negative connotation associated with Blockchain (Karuppiah et al., 2021), primarily because of the volatility of cryptocurrencies (Kamilaris et al., 2019).

Beyond organisational culture, another barrier to blockchain adoption is the resistance from external stakeholders. Blockchain, by design, removes intermediaries and intermediary partners from the supply chain; it is not uncommon to expect resistance from these entities out of fear of redundancy (Yadav et al., 2020). Furthermore, since all stakeholders in a network are never at the same level of technical maturity, resistance from partners on the lower end of technological readiness can become a barrier to large-scale adoption (Mathivathanan et al., 2021). This issue is amplified in the case of global supply chains, where the technology divide between the developing and developed world could become a significant challenge (Kamilaris et al., 2019). In this case, cultural differences between supply chain partners can also become prominent (Kouhizadeh et al., 2021).

The last, and perhaps the most critical socio-cultural barrier, is the lack of working cases in the real world. Most use-cases are mere proof-of-concepts, which fail once they get into the detailed implementation phase (Hackius and Petersen, 2020). Since Blockchain is still in its infancy, this lack of working cases makes companies and business owners hesitate to invest and experiment with Blockchain (Mathivathanan et al., 2021). This, yet again, becomes a paradox: companies are hesitant to adopt Blockchain owing to a lack of working cases, yet new working cases cannot emerge if companies do not experiment with Blockchain.

4.4 Technological

With blockchain technology being in its infancy, it is no surprise that technical barriers and enablers are discussed the most. The technological enablers are its core characteristics of traceability, immutability, and security. Kamble et al. (2019) found that traceability was the most prominent reason for blockchain adoption, followed by immutability. Since each block is linked to the previous one and information on the chain is tamper-proof, Blockchain can be used to determine provenance in food supply chains which is important for food safety and quality (Vu et al., 2021). Traceability can also improve reaction time when dealing with foodborne diseases (Katsikouli et al., 2020), such as the Hyperledger- based traceability system of Walmart, which claims to reduce provenance from 7 days to 2.2 seconds (Hyperledger, 2021). Beyond origin, traceability and immutability can also be used to protect and enforce intellectual property (IP) rights (Kurpjuweit et al., 2021) as well as to combat the problem of counterfeit products, especially drugs (Li et al., 2020).

Blockchain technology also automates these processes using smart contracts (Jardim et al., 2021). Smart contracts are simply lines of code executed when a set of pre-defined conditions are fulfilled, such as triggering a transaction once ownership of products has changed hands (Kamble et al., 2019). Smart contracts can reduce settlement times and costs by removing banks' and intermediaries' transactions (Chen et al., 2020). Furthermore, these transactions ensure privacy since transactions are cryptographically secured using ring signatures, i.e., encryption which matches and verifies the private key, which only authorised stakeholders to have, against public keys, but without revealing which one (Kamble et al., 2019). Blockchain is also safer from a cybersecurity perspective, owing to its properties of consensus, replication, and immutability (Pundir et al., 2020).

While Blockchain's properties may make it seem quite attractive, many barriers associated with it. The majority of these stem from the immaturity of the technology itself, such as scalability, which refers to bandwidth and throughput limitations, and is one of the most critical issues with Blockchain (Nurgazina et al., 2021). The entire chain must be replicated at every node whenever a new block is added. As the network scales up, latency becomes more noticeable because the replication time increases with increasing nodes (Vu et al., 2021). Multiple efforts to improve scalability have been proposed, from using different consensus mechanisms for quicker mining to various storage algorithms for lighter storage (Nurgazina et al., 2021). Even with lighter storage protocols, storage capacity remains a major constraint for scalability (Zhao et al., 2019). In most cases, the actual data is stored off-chain, with only metadata stored on the Blockchain (Kurpjuweit et al., 2021). This also constrains the ability to perform on-chain analytics (van Hoek, 2019).

Another issue with scaling up the blockchain network is the lack of interoperability and compatibility. Interoperability is the ability of one Blockchain to communicate and transact with a different blockchain system (Chang et al., 2019). Due to a lack of universal standards and the existence of multiple protocols, interoperability between different blockchain systems remains limited (Ahmad et al., 2021). This could prevent companies from participating in multiple supply chains with different businesses (Kurpjuweit et al., 2021). A related concept to interoperability is compatibility, the ability to integrate with existing IT systems of the organisation (Sternberg et al., 2020). The traditional ERP systems, for example, usually do not support blockchain integration (Jabbar et al., 2020). This is further complicated by the lack of blockchain-specific tools available to developers (Boutkhoum et al., 2021). Once again, this maps back to the immaturity of the technology and the lack of universal standards for its development (Kurpjuweit et al., 2021). Until a dominant design is reached, there is significant IT complexity associated with blockchain adoption (Ali et al., 2021).

Blockchain's cybersecurity and privacy were presented as enablers for adoption. However, Blockchain is not a 100% secure technology (Vafadarnikjoo et al., 2021), as was seen in the 2011 and 2014 hackings of Mt.Gox (Yadav et al., 2020). In addition to being vulnerable to the 51% attack (Jabbar et al., 2020), attacks such as denial-of-service (DoS) and spoofing attacks can affect the performance of the Blockchain (Etemadi, et al., 2021). Cybersecurity risks can also arise from poor programming practices in smart contracts (Ahmad et al., 2021) and through oracles which feed data from the real world to the smart contract (Etemadi et al., 2021). There is an agreement in the literature that a lack of cybersecurity leads to data and privacy breaches (Karuppiah et al., 2021). Even though several algorithms ensure privacy, there are currently no schemes that can hide the sender, receiver, and transaction simultaneously (Zhao et al., 2019). Furthermore, with the advent of quantum computing, brute force algorithms could compromise Blockchain's cryptography

(Etemadi et al., 2021). A compromised cryptographic key could expose a high volume of data (Etemadi et al., 2021). Even if a key is not compromised but simply lost, there is no way to retrieve it like a traditional password, which renders the corresponding data unusable (Liu et al., 2021).

Immutability is also paradoxically one of the most prominent barriers. Since Blockchain does not guarantee the quality of data (Jabbar et al., 2020), incorrectly entered data continues to exist in the Blockchain with no easy means of removing it (Kouhizadeh et al., 2021). Whether data is entered manually or via sensors such as RFID, the system is susceptible to the issue of garbage-in-garbage-out (Kurpjuweit et al., 2021). Immutability is also incompatible with some data protection regulations requiring data to be removed after a period (Jabbar et al., 2020). To rectify any errors in the Blockchain, a hard fork must be performed, which changes the underlying protocol and releases a new version of Blockchain, requiring every stakeholder to update to the new version (Sabbagh, 2021).

4.5 Legal/Regulatory

Blockchain's intrinsic properties of transparency and immutability make it an excellent value proposition for facilitating auditability. Current audit processes, which are paper-intensive, manual, and time-consuming, can be digitalised and streamlined if the auditor is present on the Blockchain (Kurpjuweit et al., 2021). Data integrity is guaranteed since the audit trail consists of the actual, immutable transactions themselves rather than a report of the transactions (Kamble et al., 2019). In conjunction with smart contracts, contractual misunderstandings can be mitigated since the terms of the agreement are hardcoded into the smart contract itself (Lai et al., 2021). The combination of smart contracts and an immutable record of transactions can be used to enforce intellectual property rights in case of a legal dispute (Kurpjuweit et al., 2021). Additionally, pressure to comply with tighter regulations in food supply chains regarding provenance and sustainability can act as a driver for blockchain adoption (Vu et al., 2021).

On the other hand, since Blockchain is in its infancy, there is a lack of legislation and regulation around it (Akhtar et al., 2021), and it is often cited as a barrier to adoption (Nurgazina et al., 2021). Since the nodes of a blockchain network in a supply chain can exist in multiple countries, it raises the question of which country's laws are applicable (Ahmad et al., 2021). This leads to a few complications, such as taxation issues and compliance risks (Karuppiah et al., 2021). Hackius and Petersen (2020) mention two such compliance risks, including compliance with data protection regulations and the existence of nodes in embargoed countries. In the absence of laws to regulate blockchains, companies' implementations tend to be case-specific. However, this results in the lack of a universally agreed-upon standard for blockchain development and implementation (Vu et al., 2021). The lack of regulation and standardisation creates a vacuum for illegal and fraudulent activities, such as the sale of illegal goods (Liu et al., 2021). Paradoxically, the negative perception of Blockchain due to its potential use in the underground economy induces hesitancy in policy makers and regulators (Mathivathanan et al., 2021), ultimately resulting in a barrier to blockchain adoption (Vafadarnikjoo et al., 2021).

4.6 Environmental

Blockchain has both positives and negatives regarding environmental impact and sustainability (Ada, 2022). Being digital technology, Blockchain reduces paperwork (Lai et al., 2021), which could be linked to lower reliance on the paper itself. Additionally, owing to enhanced transparency and traceability, adopting Blockchain in supply chains makes it easier to measure the carbon footprint of a product. Furthermore, there are a number of projects, such as Social Plastic and RecycleToCoin, which employ Blockchain to promote recycling plastic in exchange for monetary rewards (Saberi et al., 2018).

Conversely, Blockchain's high power requirement and infrastructure requirements have a negative environmental impact (Yadav et al., 2020). The energy requirement is due to the high computational power required to mine blocks in a Proof-of-Work (PoW) consensus algorithm (Nurgazina et al., 2021). Several alternative mechanisms have been proposed, such as Proof-of-Stake (PoS) and Delegated Proof-of-Stake (DPoS); however, they are accompanied by a compromise on security (Etemadi et al., 2021). Furthermore, as the Blockchain scales up, the increased energy consumption could outweigh the benefits of adopting Blockchain (Liu et al., 2021). Therefore, Bhardwaj et al. (2021) recommend that Blockchain only belongs in applications where the overall benefits can justify the higher power usage and increased cost.

5. Discussion

5.1 Misconceptions between Blockchain Architectures

The literature indicates a general misconception about blockchains' different architectures, i.e., public, private, permissioned, and permissionless. Public and permissionless blockchains are not ideal for applications in supply chain management. For most enterprise applications, a permission architecture is more appropriate. For example, the joint venture between IBM and Maersk, TradeLens, established a consortium blockchain which is private and permissioned (van Kralingen, 2018). Since parties on the network are pre-screened, permissioned blockchains do not require computationally intensive algorithms such as Proof-of-Work to ensure anonymity. Thus, they are much faster than their permissionless counterparts.

In order to bridge this gap, we recommend that researchers collecting primary data should begin by clarifying the different types of blockchain architectures to their participants. However, there is a need for academics to first arrive at a consensus on how to categorise these architectures. Organisations planning on experimenting with Blockchain can also benefit from a deeper understanding of these architectures. A shallow understanding of blockchain architectures leads to organisations altering their business cases to fit the available architecture. Understanding of these architectures will allow a business to fit the technology to their needs rather than the other way around and could also generate new business ideas that were previously untapped.

5.2 Lack of research on Political Enablers and Barriers

Perhaps one of the most interesting findings from this study is the lack of discussion regarding political enablers and barriers, especially considering how blockchain Blockchain has the potential to change both public and private organisations at a fundamental level. Corruption in governments and organisations is a major challenge, and the IMF estimates that bribery alone accounts for a loss of $2 trillion per year globally (Wellisz, 2018). The transparency, immutability, and auditability that Blockchain brings with it could be highly effective against bribery and corruption. The role of Blockchain in transforming governance has been explored in the literature, with some questioning whether the state is even necessary.

While this might be a little extreme at this point, there is no denying that blockchain adoption poses a threat to the current status quo. This, in turn, will naturally draw resistance from those in power. Thus, there is a need to study these direct and indirect power dynamics which influence policy development. This could also explain the lack of current laws and regulations to govern blockchains, a major barrier which is discussed in the next section.

5.3 Lack of Legislation and Regulations

The lack of legislation and regulations section introduced a number of challenges such as taxation, compliance, and customs. Current supply chains which operate across multiple borders must comply with the country-specific regulations at each border. With the adoption of Blockchain, it is possible to circumvent these regulations. For example, being a peer-to-peer technology, transactions can be made directly between supply chain parties without having to go through government-regulated taxation channels. Therefore, existing laws need to be updated to account for this new technology.

The lack of legislation is a double-edged sword. In addition to causing problems for policymakers and regulators, the uncertainty of future legislation acts as a deterrent for blockchain adoption by organisations and industries. Therefore, industry leaders must take steps to expedite the development of blockchain-specific legislations, potentially by liaising with policymakers. Furthermore, since supply chains operate across borders, this collaboration must be at a global or regional level.

The lack of universally agreed-upon standards results in issues with interoperability between different blockchains and compatibility problems between blockchains and legacy systems. GS1, a non-profit organisation which develops global standards for businesses, has already published standards to create a common language for blockchain development (GS1, 2021). However, it is interesting to note that GS1 standards were not mentioned in any of the interviews or case studies in our dataset, which indicates a lack of uptake.

Therefore, future research could focus on synthesising existing standards for blockchain development. This synthesis, in turn, could be used by industry leaders and policymakers in a joint effort to develop Blockchain- specific legislation.

5.4 Blockchain Feeding: The Difference between Success and Failure?

The lack of a unified standard for blockchain development means that companies resort to developing their own processes. While this exacerbates the problem of interoperability and compatibility, there are still lessons to be learnt from them. The interface between off-chain and on-chain is a potential point of failure for Blockchain from multiple perspectives, including data integrity and security. However, the current evidence alone is not sufficient to make this statement. There is a need to verify this empirically and through a broader comparison with other successful and failed initiatives. Future research could focus on studying failed initiatives and reaching out to those companies for an in-depth analysis of what went wrong. This could potentially uncover new barriers and challenges which have not been addressed in the literature thus far.

5.5 Environmental Impacts and Customer Perceptions

The environmental impacts of Blockchain were discussed, with the primary concern being high energy usage due to Proof-of-Work. Other mechanisms such as Proof-of-Stake were proposed as possible solutions. However, there is no indication of how much energy these mechanisms use or how much energy can be saved by switching from one to the other. More interestingly, however, is the customer perception associated with these mechanisms. The high energy consumption is often associated with Blockchain rather than Proof-of-Work itself (Sedlmeir et al., 2020). This blanket statement creates a negative perception around the entirety of Blockchain instead of permissionless blockchains. With the rising concerns around sustainability, this could bring a negative reaction from customers towards organisations which adopt blockchains. Such organisations must develop a robust media and communications strategy to ensure their customers are aware of the nuances of their technology and its impact on the environment. Therefore, it is entirely possible that customers could have a positive reaction to blockchain adoption. Not only does this differ on a case-to-case basis, but also in the effectiveness of the organisation’s communication strategy. Future research can and should explore the interrelation of customers’ perceptions and Blockchain’s environmental impacts.

6. Conclusion

This study contributes to practice by creating a PESTLE framework for barriers and enablers of blockchain adoption in supply chain management. To the best of the author's knowledge, such a framework does not exist in the literature thus far. The value of this framework lies in its simplicity and familiarity with managers. The PESTLE framework developed in this study is expected to help organisations gain a macro-level picture of how blockchain adoption will affect their business. This could result in identifying possible interlinked issues, allowing for better planning and technology adoption.

This study contributes to the wider body of knowledge by collecting and synthesising publications which focus primarily on the barriers and enablers of blockchain adoption in supply chain management. The analysis of these publications uncovered dominant research patterns and showed that barriers and enablers had been discussed most often in the food industry. Furthermore, the analysis reveals that barriers were more often discussed than enablers. Gaps in the literature were identified, such as the absence of political challenges, and links were suggested between themes such as customers' reactions to environmental impacts, both positive and negative. A number of future research directions are also presented in the next section.

This research identifies a number of streams for future research:

- The study categorises barriers and enablers into a PESTLE framework; however, there is a need for empirical verification of this framework. Future research could improve this framework by testing it with industry experts.
- The study identifies a lack of political barriers as a gap in the existing literature. Future research could investigate the interplay between politics and its effects on blockchain legislation.
- The study identifies a missing link between the environmental impacts of Blockchain and customers' reactions to it. Future studies could observe customers' reactions to companies that have implemented Blockchain or are in the process of doing so.
- The lack of managers' understanding of Blockchain has been a cornerstone of this study; however, there is a need to specifically study the gaps in the industry's knowledge about Blockchain. Future researchers could help bridge these gaps by investigating managers' perceptions of Blockchain.
- Lastly, the dataset obtained in this study does not mention COVID-19, nor does it consider the effects of this pandemic on the adoption of Blockchain in supply chain management. This is most likely because the pandemic is quite recent and still ongoing. However, future researchers can and should investigate the effects COVID-19 has had on supply chains and their attitude towards technology adoption.

There are several limitations associated with this study. First, the study does not factor in the COVID-19 pandemic, which has shaken up the entire world. Secondly, the validity of the PESTLE framework remains to be tested. Lastly, the time horizon for this study is cross-sectional, with a minor longitudinal element in the thematic evolution. This is due to the novelty of the research field, and it is expected that longitudinal studies will be possible in the future as this research field continues to grow.

Conflict of interest

We do not have any conflict of interest

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