How Does Blockchain Application Impact on Supply Chain Alliance?

Ji Yan[a] , Qinchang Gui [b], Sitong Jiang [a], Zihao Yu [a c], Kieran Fernandes [a], Kun Tian [d], Senmao Xia [e], Yu Gong [f]

[a] Business School, Durham University, Mill Hill Lane, Durham, DH1 3LB, UK

[b] School of Geographical Sciences, Southwest University, Chongqing, 400715, China

[c] School of Innovation and Entrepreneurship, Hunan Normal University, Changsha, 410081, China

[d] Kent Business School, University of Kent, Central Avenue, Chatham, ME4 4AG, UK

[e] Surrey Business School, Surrey University, Guildford, Surrey, GU2 7XH, UK

[f] Southampton Business School, University of Southampton, University Road, Southampton, SO17 1BJ, UK

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Abstract

Recent advancements in blockchain technologies have attracted significant global attention in supply chain management due to their potential to revolutionize this field. Our study examines the relationship between a firm's blockchain application and its alliances with supply chain partners at a dyadic level. Furthermore, the study sheds light on the influence of geographical and technological proximities as critical contextual factors in this dynamic. This study predicts that blockchain integration within a firm fosters the formation of supply chain alliance between firms, with the positive effect being amplified when firms are geographically and technologically closer. Such proposition is evidenced by analysis based on a comprehensive dataset compiled from public annual reports, details of supply chain partnerships, and patent records of 3,281 Chinese listed firms over the period 2012–2020. This research offers novel insights into how emerging technologies foster trust-based collaboration within supply chains, and contributes not only to the expanding literature on blockchain applications in supply chain management, but also addresses the need for a deeper understanding of how specific contextual factors, such as geographic and technological proximity, shape the impact of blockchain integration.

Keywords

Blockchain application; Supply chain alliance; Supply chain network; Geographical proximity; Technological proximity

1. Introduction

The COVID-19 pandemic accelerated blockchain adoption in supply chains as companies and governments sought to improve transparency, resilience, and efficiency (Hewett, Søgaard, and Mølbjerg 2020). Blockchain applications, which encompass the adoption, implementation, and integration of blockchain technology within a firm’s operations (Ahmed, MacCarthy, and Treiblmaier 2022; van Hoek 2019), enhance data visibility, traceability, and transparency for supply chain actors (Chod et al. 2020; Cui, Gaur, and Liu 2023). Moreover, blockchain fosters interorganizational trust and competitive advantage within the supply chain networks (Pun, Swaminathan, and Hou 2021; Queiroz, Telles, and Bonilla 2019). Although research on the impacts of blockchain technology is still developing, studies suggest that it has the potential to be extended to reshape firm interactions across supply chain networks, offering a potentially valuable theoretical framework for understanding firm-stakeholder engagement within these networks (Ertug et al. 2022; Treiblmaier 2018).

It is crucial to understand the overall impact of blockchain applications on supply chain alliances, as this knowledge can help businesses make informed decisions about blockchain implementation and guide research that supports future supply chain innovations. However, it remains uncertain whether blockchain applications positively impact the formation and support of supply chain alliances. This ambiguity arises from blockchain’s dual impact, as it offers both advantages and disadvantages within supply chain networks.

On the positive side, blockchain can enhance transparency, streamline data sharing, and enhance traceability among supply chain partners, potentially fostering trust and collaboration within alliances (Vazquez Melendez, Bergey, and Smith

2024). On the downside, blockchain introduces significant challenges, including high environmental costs due to energy-intensive operations and risks to data privacy, as sensitive information might be exposed even in controlled blockchain systems (Wegrzyn and Wang 2021) . Additionally, scalability limitations and high implementation costs pose barriers, with slower transaction speeds and upfront expenses hindering adoption, particularly in high-volume supply chains (Budhi 2022). For example, blockchain's high energy consumption, combined with potential data privacy risks and worker surveillance issues, may deter partners who prioritize ethical standards (Aste, Tasca, and Di Matteo 2017). Such concerns could harm a company's image and make it harder to form alliances with other supply chain participants.

Given these contrasting effects, addressing the dual impacts of blockchain applications is necessary to unlock blockchain's full potential as a tool for strengthening alliances, fostering long-term sustainability, and achieving competitive advantage in increasingly interconnected markets. This approach addresses a critical gap in current research regarding the effect of blockchain applications on the formation and maintenance of supply chain alliances. To address this gap, our research objective is to examine how blockchain applications influence the establishment and maintenance of supply chain alliances and to determine the conditions under which blockchain is most likely to support or hinder these partnerships.

Moreover, blockchain alone cannot fully account for the formation and strength of supply chain alliances; thus, additional moderators, such as geographical and technological proximity, are necessary to deepen our understanding of how these contextual factors enhance or constrain blockchain's impact on collaboration and trust within the network. Key among these are physical and cognitive factors, represented here by geographical and technological proximity (Boschma 2005; Rothaermel and Boeker 2008). The contextual impacts of these two factors are theoretically important yet underrepresented in prior studies. Unlike other forms of contingencies that arise from cultural or institutional barriers (e.g., cultural proximity and institutional proximity) (Hong and Su 2013; Schmitt and Van Biesebroeck 2013), geographical and technological proximity could explain the effectiveness of blockchain application in shaping supply chain operations with novel insights in terms of trust-building, knowledge sharing, and efficient cooperation.

Firstly, geographical proximity, or the closeness between firms, offers valuable insights. Research shows that geographical distance hinders tacit knowledge exchange via face-to-face interactions and raises communication and cooperation costs, which impacts trust-building in blockchain applications (Geldes et al. 2015; Knoben and Oerlemans 2006). Thus, geographical proximity plays a critical role in understanding the relationship between blockchain and supply chain alliances, as it directly affects communication and trust-building.

Secondly, technological proximity—the similarity in firms' knowledge stocks (Boschma 2005; Nooteboom 2000)—also enhances blockchain's impact by facilitating knowledge sharing. A similar knowledge base allows firms greater opportunities to exchange domain knowledge and expertise (Belchior et al. 2021; Schulte et al. 2019), fostering stronger cooperation and trust-building process (Liu et al. 2021). Consequently, the support provided by technological proximity can strengthen the relationship between blockchain applications and supply chain alliances.

Taken together, we find that prior studies have overlooked how blockchain applications foster mutual trust and interorganizational resource sharing, as well as the role of geographical and technological proximity in enhancing these effects (Hastig and Sodhi 2020; Wang, Han, and Beynon-Davies 2018). To address the gap, we aim to ask and answer the research question: *How do blockchain application affect supply chain alliance and how do geographical and technological proximity moderate such relationship?*

The novelty of this study lies in its dual contributions. Firstly, this study advances theoretical understanding of blockchain technology by investigating its foundational role in shaping supply chain alliances. While prior research has examined blockchain’s impacts on supply chain operations and strategy, there remains a gap in understanding how these applications drive networked outcomes within supply chains (Queiroz et al. 2019; Treiblmaier 2018). This study addresses this gap by analyzing blockchain's direct influence on network dynamics and alliance formation, clarifying its tangible, measurable benefits and reducing uncertainties around its real-world applications. By adopting a network perspective, this research offers a nuanced view of how blockchain fosters the formation and sustainability of alliances within supply chains, helping to resolve contrasting perspectives on its effectiveness (Huang, Han, and Macbeth 2020; Stolwijk, Ortt, and Den Hartigh 2013).

Secondly, this study enriches the alliance literature by providing insights into how geographical and technological proximity moderate the impact of blockchain technology in shaping alliance formation within the supply chain network. Prior research largely overlooked the role of the between-firm proximities as contextual factors, focusing instead on the direct effect of these proximities in shaping network outcomes (Hansen 2015; Houé and Duchamp 2021) or on interactions between different types of proximities (Christoffersen 2013; Ertug et al. 2022). By investigating the contingent roles of geographical and technological proximity, our study demonstrates how proximity factors act as critical moderators, enhancing blockchain's effectiveness in fostering trust and resource sharing within alliances. Furthermore, our study extends the exploration by examining how these proximities, as important contextual factors alongside organizational-level characteristics (i.e., blockchain application), affect alliance formation within the supply chain network, thereby advancing theoretical understanding in this domain (Phene and Tallman 2014; Rothaermel and Boeker 2008). By addressing these underexplored areas, the study bridges blockchain, proximity, and alliance literature, offering both theoretical advancements and practical implications for supply chain networks.

2. Literature review

2.1 Blockchain and Impacts

Blockchain serves as a decentralized digital ledger technology, adept at securely recording and interlinking transactions across a network. Employing cryptographic methods, it ensures transparency, tamper-resistance, and data integrity (Kumar, Liu, and Shan 2020). Globally, there is a considerable interest in transformative potential of blockchain technology for supply chain management and its contribution to sustainability goals (Kouhizadeh, Saberi, and Sarkis 2021; Yousefi and Mohamadpour Tosarkani 2022). Prior research has examined blockchain application across various industries, including but not limited to the food, healthcare, finance, minerals, retail, vaccines and logistic industries (Gupta et al. 2023; Kouhizadeh et al. 2021).

In supply chain management, blockchain's impact manifests as behavioral, cognitive and performance outcomes. Firstly, **behavioral outcomes** involve operational applications (e.g., smart manufacturing, sustainability efforts), financial applications (e.g., supplier financing, green loans), data sharing, and fraud mitigation (Queiroz et al., 2019). Blockchain addresses challenges in data sharing (Wang et al., 2021), combats counterfeits (Pun et al., 2021), supports traceability (Hastig & Sodhi, 2020), and influences quality management (Cui et al., 2023).

Firstly, the behavioral outcomes studied encompass operational applications (e.g., smart manufacturing and sustainability efforts), and financial applications (e.g., financing for suppliers and green loans). Additionally, they extend to data sharing and information consistency in supply chain management, and the establishment of trust and sustainability through consensus mechanisms to mitigate fraud (e.g., Queiroz et al. 2019). The influence of blockchain application on supply chain management is further evident in their ability to address challenges related to data sharing (Wang et al. 2021), combat copycat and counterfeit issues in retail (Pun et al. 2021; Shen, Dong, and Minner 2022; Zhu et al. 2023), act as a traceability system meeting business requirements (Hastig and Sodhi 2020), impact quality management in diverse supply chain structures (Cui et al. 2023), adopt in financing schemes for three-tier suppliers (Dong, Qiu, and Xu 2023), and model product-information-disclosure for rental service platforms (Choi, Feng, and Li 2020).

Secondly, within the domain of behavioral outcomes, the discourse on cognitive outcomes emerges. Research posits that the implementation of blockchain by firms can effectively reduce distrust level among actors within supply chain network (Biswas et al. 2023). Furthermore, blockchain is demonstrated to mitigate misuse of green loans, enhance supply chain efficiency and participant profits, and outperform traditional institutions in the information environment (C. Wang et al. 2023; M. Wang, Li, and Song 2023).

Thirdly, performance outcomes encompass the overall supply chain performance, including enhanced responsiveness, efficiency, and transparency, as well as advancements in traceability and quality management (e.g., Wang et al. 2018). Blockchain applications also contribute to increased profits for manufacturers, reduced delivery time, and improved consumer information symmetry under specific conditions (Xu et al. 2023). Specifically, through the enabling of smart contracts and manufacturing, blockchain enhances responsiveness, efficiency, visibility, trust, security, transparency, sustainability, traceability, and information sharing, concurrently reducing lead time and transaction costs (Bai and Sarkis 2022; Queiroz et al. 2019).

While blockchain offers significant benefits, its negative impacts cannot be overlooked. High energy consumption, necessary for secure operations, raises environmental concerns that conflict with sustainability goals (Aste, Tasca, & Di Matteo, 2017; Jiang et al., 2021). Data privacy risks also arise, as sensitive information may still be vulnerable even in controlled blockchain systems, leading to hesitancy among partners with strong ethical standards (Forbes Technology Council, 2022). Additional challenges include scalability and high implementation costs, as blockchain's slower transaction speeds and significant upfront expenses reduce its practicality in high-volume supply chains (van Hoek, 2019). Blockchain's immutability can also propagate data entry errors and fraud, as incorrect data cannot easily be corrected, creating trust concerns within collaborative networks (Foley & Lardner LLP, 2021). Furthermore, studies highlight other negative outcomes such as increased uncertainty around costs and benefits, technical and organizational challenges, elevated storage costs, and environmental unfriendliness (Kouhizadeh et al., 2021; Yadav, Shweta, & Kumar, 2023; Kumar et al., 2020; Biswas et al., 2023).

Existing research highlights blockchain's benefits and drawbacks for supply chain performance, such as transparency and traceability, but lacks a comprehensive understanding of how these attributes support the formation and maintenance of supply chain alliances, specifically in facilitating alliance formation, maintaining collaborative relationships, fostering mutual trust and interorganizational resource sharing within the supply chain.

As shown in Table 1, the existing gaps include the uncertainty about the tangible, measurable benefits that blockchain brings specifically to supply chain alliances, despite its known ability to enhance supply chain performance through improved data sharing and traceability (Streams 1 & 2). Furthermore, there is a lack of understanding regarding how blockchain directly influences supply chain network dynamics and alliance formation (Stream 3). Additionally, knowledge gaps and limited digital literacy among supply chain partners hinder the effective adoption and utilization of blockchain in alliances (Streams 4 & 5).

Following prior studies, such as Cui, Gaur, and Liu (2023), there remains a specific gap in understanding how blockchain's attributes support the formation and maintenance of supply chain alliances. While blockchain is known to enhance transparency and data sharing, its role in facilitating and sustaining alliance formation, fostering mutual trust, and promoting interorganizational resource sharing needs more exploration. For instance, Dehshiri et al. (2024) discuss the integration of blockchain with strategic alliances in the renewable energy supply chain (RESC) and highlight the role of blockchain in improving trust and cooperation through features such as transparency, traceability, decentralization, and security. However, the paper does not thoroughly explore how blockchain specifically facilitates and sustains alliance formation beyond enhancing trust and information sharing. While it suggests blockchain's potential for improving strategic alliances by addressing risk and enabling better coordination, it does not delve into detailed mechanisms for fostering mutual trust or promoting interorganizational resource sharing across diverse supply chain contexts. Additionally, Dubey et al. (2020) highlight how blockchain can build swift-trust and enhance collaboration within humanitarian supply chains; however, they note that more research is needed to generalize these findings to other contexts, particularly regarding formal alliances across industries. The paper's focus remains limited to disaster relief scenarios, missing the opportunity to discuss how blockchain could support sustained alliances and the development of mutual trust in more diverse supply chain networks, which represents a gap in the current research.

Furthermore, Kostić and Sedej (2022) discuss blockchain's role in enhancing inter-organizational relationships (IORs) through improved management accounting practices, trust-building, and control mechanisms. The paper focuses on blockchain's impact on governance, control, and information exchange within established partnerships, emphasizing its potential for decentralized information management, tamper-proof records, and smart contracts. However, it does not explore how blockchain could facilitate the initial formation of alliances, foster mutual trust in new relationships, or promote interorganizational resource sharing across diverse supply chain contexts, leaving a gap in understanding its role in forming and sustaining strategic alliances.

Table 1: Overview of studies discussing blockchain and supply chain

Authors	Main Stream	Summary of Empirical Findings	Theories	Identified Gaps
van Hoek (2020a), van Hoek (2020b), Galati (2022), Sodhi et al. (2022), Agi and Jha (2022), Ahmed et al. (2022), Baharmand et al. (2021), Van Hoek (2019), Danese et al. (2021)	Drivers of Adoption of Blockchain in Supply Chain	Technological and Operational Drivers: Enhancing transparency, traceability, cost savings, and efficiency. Organizational Drivers: Readiness, leadership support, aligning goals, top management support, cost considerations. External and Market Drivers: Regulatory pressures, industry partnerships, managing supply chain risk. Innovation and Technology Drivers: Novelty, blockchain engagement, and tech alternatives, supply chain learning/collaboration. Socio-Cognitive Drivers: Knowledge assets, system compatibility, and adoption motivators.	Various theories including social capital theory, affordance theory, Diffusion of Innovation (DOI), and technology adoption models.	Uncertainty about the benefits and costs of blockchain implementation in the supply chain
Kouhizadeh et al. (2021), Yadav et al. (2023), Baharmand et al. (2021)	Barriers to Adoption of Blockchain	Technological: Security, immaturity, expertise, infrastructure. Organizational: Resistance, structural changes, resources, scalability. External: Regulations, privacy, market adoption. Supply Chain: Integration, scalability, trust.	Technology-Organization-Environment (TOE) framework, technology adoption theories, force field theories	Uncertainty about the impact of blockchain on supply chains, concerns over scalability, regulatory challenges, and lack of technical skills.
Zelbst et al. (2023), Ying et al. (2023), Ma and Hu (2022), Gupta et al. (2023), Wamba et al. (2020), Yousefi et al. (2022), Khan, Mubarik, Kusi-Sarpong, Gupta, Zaman, & Mubarik (2022), Tiwari, Sharma, Choi & Lim (2023), Asokan, Huq, Smith & Stevenson (2022)	Effect of Blockchain on Supply Chain Operational Performance	Blockchain enhances supply chain performance, sustainability, resilience, and consumer purchase by improving transparency, traceability, and integration in supply chain operations. Blockchain implementation challenges include technology complexity, regulatory issues, and costs.	System theory, signaling theory, transaction cost economics, resource dependence theory	Difficulties in scaling blockchain solutions, regulatory compliance issues, and high implementation costs
Brookbanks and Parry (2022), Zelbst et al. (2023), Nandi et al. (2020), Rogerson and Parry (2020), Ahmed and MacCarthy (2023), Gligor, Davis-Sramek, Tan, Vitale, Russo, Golgeci & Wan (2022)	Effect of Blockchain on Relationship and Information	Blockchain improves supply chain trust, transparency, visibility, traceability, and information sharing, facilitating better buyer-supplier relationships and coordination in supply chains.	Principal-agent theory, resource-based view, resource orchestration theory	Integration challenges, high costs, and limited digital literacy among supply chain partners hinder widespread adoption
Giri and Manohar (2023), Giovanni (2022), Song et al. (2023), Benzidia, Makaoui, & Subramanian (2021), Dehshiri, Amiri, Mostafaeipour & Le (2024), Dubey, Gunasekaran, Bryde, Dwivedi & Papadopoulos (2020), Durach, Blesik, von Düring, & Bick (2021), Nayal, Raut, Narkhede, Priyadarshinee, Panchal, & Gedam (2023), Vazquez Melendez, Bergey & Smith (2024)	Collaboration, Integration, and Governance of Blockchain	Blockchain collaboration, integration, and governance enhance supply chain (SC) performance, innovation capability, resilience, SC efficiency, trust, transparency, and sustainability. It supports better decision-making, operational performance, and consumer trust, with perceived usefulness, perceived ease of use, and technology uncertainty acting as mediators. However, challenges include integration, costs, and lack of expertise.	Technology Acceptance Model, Organizational Information Processing Theory, Technology-Organization-Environment, and dynamic capabilities theory	High implementation costs, regulatory barriers, integration challenges, and knowledge gaps in using blockchain effectively.

2.2 Supply Chain Alliance

A supply chain alliance denotes a collaborative relationship between two or more entities within a supply chain, comprising stakeholders such as suppliers, manufacturers, distributors, and retailers. Classification of such alliances is categorized by criteria like strategic, tactical, innovative, global/local, and dyadic alliances (Nyaga, Whipple, and Lynch 2010). Previous studies mainly examined antecedents through firm-level or dyadic-level analyses (e.g., Gimeno 2004; Sambasivan et al. 2013). This study adopts a dyadic-lever perspective, focusing on the nuanced one-to-one relationship between two entities (e.g. one manufacturer and one retailer).

Antecedents of alliance formation are typified into relational, structural, and cognitive factors (Appio et al. 2017). Relational factors refer to the nature of relationships, encompassing dimensions such as trust, evaluation, reputation, and motives (Liu, Hull, and Hung 2017). Structural factors encompass supportive architectures and information technology (Stolwijk et al. 2013), while cognitive factors pertain to the knowledge and competencies of human resources, including elements such as cultural differences and similarities between entities or components (Christoffersen 2013; Sengupta and Perry 1997).

Notably, with the context of blockchain-related attributes, understanding and leveraging trust and relatedness emerge as integral facets of successful alliance formation. Trust in alliance formation pertains to the confidence, reliance, and belief in the reliability and intentions of the counterpart within the supply chain (Tejpal, Garg, and Sachdeva 2013). It assumes a pivotal role in alliance formation, influencing performance and serving as a key element within relational factors. The construction of trust involves multifaceted processes, including the provision of technical and financial assistance, augmentation of interdependence and relational capital, all of which collectively impact strategic alliance outcomes (Sambasivan et al. 2013). Relatedness, conversely, refers to similarities in business activities, products, and industries among the participating organizations. In the realm of international strategic alliances, the selection of partners based on relatedness is crucial, as disparities in size can damage alliance performance, giving rise to other detrimental dissimilarities (Christoffersen 2013).

Interestingly, extant literature lacks exploration into the antecedent role of blockchain application on supply chain alliances. The acquisition of dyadic-level data from supply chain actors associated with the focal firm poses considerable challenges. Consequently, this study endeavors to contribute a dyadic-level analysis elucidating the impact of blockchain application on the dynamics of supply chain alliances.

2.3 Geographical and technological proximity

Proximity, defined as the similarity or closeness between different characteristics of two organizations (Knoben and Oerlemans 2006), is employed in our study to comprehend and analyze the relationships between different entities within a network. We contend that proximity significantly influences the efficiency, cost, and overall performance of a supply chain.

This study focuses on geographical and technological proximities, aligning with calls for research in the contextual and temporal circumstances of interaction with market, society and environment (Kewell, Adams, and Parry 2017). Geographical proximity refers to the physical closeness or spatial nearness between nodes (entities or locations) within a network (Schmitt and Van Biesebroeck 2013; Torre 2008). It can reduce transportation costs, shorten lead times, facilitate communication and better coordination, mitigate risk, transfer knowledge and enhance local market understanding (Torre 2008). Trust is considered a crucial outcome of geographical proximity, as physical closeness supports frequent face-to-face interactions, enhances understanding, and allows swift response to potential disruptions (Knoben and Oerlemans 2006).

Moreover, technological proximity refers to the similarity or compatibility in technological capabilities, knowledge, and innovation processes between network nodes (entities) (Boschma 2005). It emphasizes shared technological characteristics and expertise among network participants and how these similarities influence their interactions and collaborations. Technological proximity influences firm-level knowledge exchange, innovation collaboration, technology adoption, competitive advantage, technological alignment, risk mitigation, talent pool, common technological standards, and industry cluster aggregation (Wu, Yuan, and Guo 2023). Therefore, characteristics of technological proximity include the similarity between the knowledge and technology stock, and shared mindsets between the two firms (Park and Ghauri 2011).

The contextual impacts of these two factors are theoretically important yet underrepresented in the blockchain application studies. Prior research focus on direct effect or interaction effect between different proximities on network alliances (e.g., Guo et al. 2021). These studiessuggest that proximities can reduce communication and coordination costs, thereby enhancing trust-building and collaboration efficiency (Boschma 2005; Geldes et al. 2015). This perspective is further explained through the theoretical lens of resource-based view, which posits that proximity enables firms to better leverage shared resources and capabilities (Presutti et al. 2019). Given that the impacts of contextual factors are often overlooked when examining the implementation and adaptation of advancing ICT technologies (Goldenberg and Levy 2009), prior discussions have missed the opportunity to examine the contingent role of proximity in shaping the blockchain application process. Instead, this study examines how both proximity and firm-level characteristics jointly influence supply chain alliances. The lack of practical guidelines for implementing blockchain in diverse supply chain contexts is a key challenge. Research is needed to offer actionable recommendations, considering factors like geographical and technological proximity, which can influence the success of blockchain initiatives.

According to Table 1, the existing research gaps include a limited understanding of how geographical and technological proximity (physical distance and technological capabilities) impact supply chain alliances (Stream 1). The role of these proximity factors in enhancing blockchain's effectiveness across networks remains underexplored, particularly given blockchain’s scalability limitations, which may be affected by whether partners share a common technological infrastructure or are situated close enough for rapid communication and troubleshooting (Streams 3 & 4). Additionally, a research gap exists in understanding how digital literacy and disparities in blockchain knowledge, influenced by proximity, affect the technology's effectiveness in fostering supply chain alliances. Specifically, while partners in close proximity may benefit from easier knowledge sharing and training, those farther apart may face challenges with consistent training, potentially hindering successful blockchain adoption and collaboration (Stream 5).

Prior studies (e.g., Queiroz, Telles, and Bonilla 2020) indicate that the lack of practical guidelines for implementing blockchain in diverse supply chain contexts presents a significant challenge. We aim to address the need for research to provide actionable recommendations, considering factors such as geographical and technological proximity, which can influence the success of blockchain initiatives. For example, Xu et al. (2022) focus on how congruence and incongruence between blockchain and relational governance mechanisms, particularly the norm of solidarity, interact to build trust in supply chain relationships. They primarily discuss technology uncertainty as a general moderator in the relationship between blockchain and trust. However, the paper leaves a gap in considering other moderators, such as geographical and technological proximity, in shaping the effect of blockchain on supply chain alliances or networks with respect to trust. It does not explore how factors like physical distance or technological compatibility might influence the dynamics of blockchain's impact on alliance formation and interorganizational collaboration, highlighting an area for further investigation.

Furthermore, Tiwari et al. (2023) address the adoption of blockchain in third-party logistics (3PL) for global supply chains, proposing a framework and roadmap for blockchain implementation. While the paper provides a comprehensive overview of the benefits and challenges of using blockchain technology, it lacks detailed guidelines for specific factors, leaving a gap in offering actionable recommendations tailored to scenarios where geographical distance or varying levels of technological advancement among partners may affect the effectiveness of blockchain in facilitating supply chain alliances. Further research could explore how proximity factors, such as geographical and technological proximity, influence blockchain adoption and its impact on interorganizational collaboration and network dynamics, which is another focus of this research.

3. Hypotheses

3.1 Blockchain application and supply chain alliance

We propose that the integration of blockchain technologies significantly promotes the development of supply chain alliances by enhancing supply chain efficiency, broadening the scope for partnerships, solidifying interorganizational trust, and amplifying bargaining power. **Firstly**, blockchain application contributes to supply chain efficiency by amplifying a firm's network influence and multiplying alliance prospects (Hastig and Sodhi 2020; Wang et al. 2018). Prior studies show that blockchain applications are linked to improved data visibility and lowered operational cost (Agi and Jha 2022; Ahmed and MacCarthy 2023), which, in turn enhances operational transparency and traceability, diminishing information asymmetry among stakeholders. Better information transparency aids in streamlining supply chain activities and fosters collaborations (Brookbanks and Parry 2022; Zelbst et al. 2023). Further, blockchain's influence extends the firm's and its close supply chain partners' significance within the supply chain network by drawing interest from external organizations seeking unique resources, greater operational efficiency, and cost reductions (Nandi et al. 2020; Swierczek 2019). This benefit, in turn, leads to more alliance opportunities. Thus, blockchain application not only fortifies the success of current supply chain alliances but also paves the way for future partnerships with an expanded roster of supply chain participants.

Secondly, blockchain applications enhance interorganizational trust and collaboration, reinforcing firms' ability to negotiate alliances within supply chain networks and improving entity credibility supported by secure, effective cooperation. Research suggests that blockchain applications could mitigate the issue of copycat and counterfeit, thereby protecting product authenticity and augmenting brand value (De Giovanni 2022; Ma and Hu 2022). Consequently, firms gain higher level of interorganizational trust within the supply chain through committed, transparent collaborations under mutually agreed conditions (Brookbanks and Parry 2022; Queiroz et al. 2019). Moreover, firms that proactively adopting blockchain technology also set higher collaboration standards due to the technology's inherent norms and commitments (Baharmand, Maghsoudi, and Coppi 2021; van Hoek 2019). Blockchain's consensus mechanisms assure the dissemination of precise information, aligning all partners with agreed-upon standards and commitments, which in turn ensures adherence and a higher level of accountability (Baharmand et al. 2021). These benefits can be translated into increased interorganizational trust and negotiating power for the focal firm in attracting new partners within the supply chain network (Brookbanks and Parry 2022; Swierczek 2019).

Therefore, we posit that:

H1. Blockchain application is positively related to the supply chain alliance between two firms.

3.2 The moderating role of geographical proximity

While blockchain technology enables companies to communicate across long distances, certain aspects of trust-building cannot be fully explained by this technology alone. Studies show that geographical distance remains a significant obstacle to collaboration (Katz 1994; Knoben and Oerlemans 2006), even in the blockchain era (Zook and McCanless 2022). This is because geographical distance not only reflects the physical space between two actors but also may indicate unobservable differences in longitudinal characteristics, such as cultural background, administrative status, and resource disparities (Goldenberg and Levy 2009; Knoben and Oerlemans 2006; Presutti et al. 2019). These factors, represented by geographical distance, could directly influence the interaction preferences of two actors regarding communication and collaboration (Bignami, Mattsson, and Hoekman 2020; Parreira et al. 2017). Studies also explored its impacts as contextual factors in a supply chain setting, and suggest that geographical distance plays a key role in shaping trust-building and collaboration process (Bönte 2008; Wiengarten and Ambrose 2017).Therefore, in this context, geographical distance affects trust-building and cooperation differently than digital solutions like blockchain can.

Geographical proximity between the firms enhances the trust-building process, resource sharing, and operational efficiency, thereby amplifying the impact of blockchain application on the formation of supply chain alliances. **Firstly**, geographical proximity accelerates trust-building among current and potential supply chain partners by reducing communication costs, thereby facilitating information and tacit knowledge exchange (Boschma 2005; Huang and Fan 2022). It creates an environment conducive to in-person meetings for collaborations (Huang and Fan 2022; Schmitt and Van Biesebroeck 2013), and allows for direct inspections and evaluations of operations and capabilities, reinforcing agreed-upon commitments and quality standards (Torre 2008). Moreover, close geographical proximity typically implies a shared physical, cultural, and regulatory environment, enhancing mutual understanding of local context (regulations, market dynamics, etc.) (Chung, Sul, and Wang 2021; Ojala 2015). Consequently, the frequent interactions and ease of monitoring operations foster trust among supply chain partners and enhance the efficacy of blockchain.

Secondly, geographical proximity promotes resource sharing and operational efficiency, vital for the effective application of blockchain in supply chains. With blockchain's demands for computing resources and digital infrastructure (van Hoek 2019; Yadav, Shweta, and Kumar 2023), closely situated partners are more likely to encourage in resource exchanges for blockchain integration, addressing the technical challenges and risks associated with its adoption (Hinzmann, Cantner, and Graf 2019; Holdt Christensen and Pedersen 2018). For example, supply chain partners that are close to each other find it easy to share digital infrastructure and mitigate possible risks arising from technical issues or unexpected challenges when integrating blockchain into supply chain collaborations (Biswas et al. 2023; Biswas and Roy 2007). Enhanced resource sharing in turn saves the resources and attentions for conducting efficient supply chain collaborations, contributing to a better overall performance of the firm and its supply chain partners in the network. This collaboration conserves resources, leading to superior performance and competitive advantage, thereby enhancing a firm's ability for form new alliances (Baharmand et al. 2021; Brookbanks and Parry 2022; Swierczek 2019). Thus, geographical proximity acts as a catalyst for operational efficiency, streamlining the transformation of blockchain's benefits into successful supply chain alliances.

Therefore, we posit that:

H2. Geographical proximity positively moderates the relationship between blockchain application and supply chain alliance.

3.3 The moderating role of technological proximity

We propose that technological proximity between supply chain partners mitigates the needed for extensive resources in communicating and learning, thereby streamlining effective collaboration and enhancing the impact of blockchain application on alliance formation. **Firstly**, technological proximity between two supply chain actor lowers the barriers to communication and learning, evidenced by faster decision-making and cooperative processes when a shared technological understanding exists (Cantner and Meder 2007; Guan and Yan 2016). The uniform adoption of blockchain standards and protocols across the supply chain network, as encouraged by blockchain's inherent design, becomes more straightforward with aligned technological backgrounds (Baharmand et al. 2021). The aligned technological background simplifies the integration and implementation of blockchain technology by lowering the cost for supply chain partners in learning and accommodating to the common standard, thereby leads to seamless resource sharing and communication among supply chain partners,

Secondly, technological proximity leads to more efficient supply chain operations and a more potent transformation of the benefits of blockchain application into successful supply chain alliances. Technological proximity could pave the way for smooth and effective collaborations. With higher interoperability facilitated by similar technological infrastructures, integration of blockchain into existing systems becomes less complex (Belchior et al. 2021; Schulte et al. 2019). The reduced complexities and costs regarding blockchain applications thus contribute to a faster and more efficient process of alliance building and improve the efficiency in supply chain collaborations. Moreover, with similar mindsets and approaches, the technological knowledge and expertise from both sides could be jointly utilized to reach a better understanding of the benefits of blockchain applications (López-Pintado et al. 2022), fostering the development of blockchain solutions tailored to the network's collective needs (Liu et al. 2021). These improvements subsequently underpin the firm's operational efficiency and competitive advantage, amplifying the role of blockchain applications in driving alliance-building within the supply chain.

Therefore, we posit that:

H3. Technological proximity positively moderates the relationship between blockchain application and supply chain alliance.

Taken together, we summarize the conceptual model in Figure 1.

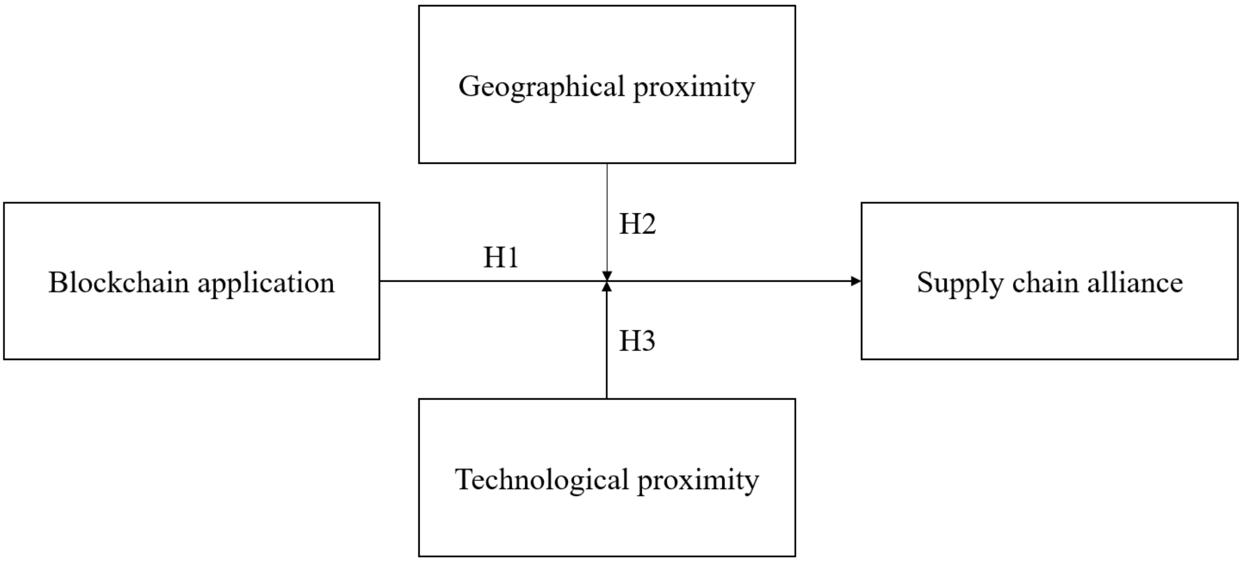

Figure 1 The conceptual model

4. Data and Methodology

4.1 Sample and data collection

To test the hypotheses, we use a sample of Chinese listed firms. Firstly, supply chain network is constructed based on the supplier–customer relationship. From 2011, Chinese listed firms have been encouraged to disclose information about their top-five suppliers and customers in annual reports. This non-mandatory policy issued by the China Securities Regulatory Commission offers a good opportunity to observe their supply chain collaborations in the listed firms (Y. Wang et al. 2023). We use the information of all listed firms' top five suppliers and top five customers from 2012 to 2020 documented in the China Stock Market and Accounting Research database (CSMAR), to construct the supply chain network (Yan et al. 2023). Secondly, to capture blockchain application, we use the information that mentioned "blockchain", "blockchain technology", "blockchain application", etc., in the public annual report of the listed firm. We also collected the patent data of each listed firms using the China National Intellectual Property Administration (CNIPA) platform. The geographical information and financial information of all listed firms are also collected using the CSMAR database. Given the data availability, the final sample contains the records of 3281 Chinese listed firms from 2012 to 2020.

4.2 Variables and Measures

4.2.1 Dependent variable

We measure supply chain alliance in the changing supply chain network. The supply chain network is a binary matrix, denoted by $x = (x_{ij})$, where x_{ij} represents the relation directed from firm *i* to firm *j*. There is a tie from node *i* to node *j*, $x_{ij} = 1$, or absent, denoted $x_{ij} = 0$. Self-ties are not considered, so that the diagonal is structurally zero.

4.2.2 Independent variable

Following prior studies, we collect text data about blockchain application from the listed firms' annual reports (Autore, Clarke, and Jiang 2021; Tawiah et al. 2022). We use the number of blockchain related sentences in the public annual report of each Chinese listed firms to represent the extent of the firm's blockchain application. Specifically, we search each report manually to identify any mention of blockchain adoption. For example, we use keywords such as blockchain, block, and crypto to match any blockchain related information in the annual report (Tawiah et al. 2022). More blockchain related sentences in the annual report indicate a higher level of application of blockchain technology of the firm.

4.2.3 Moderators

Geographical proximity. Following previous research (Broekel and Boschma 2011; Phene and Tallman 2014), we use the spherical distance between two firms divided by 1 to measure the geographical proximity. The distance was calculated based on the geographical coordinates of the two firms. The higher the value, the greater the geographical proximity.

Technological proximity. Technological proximity reflects the similarity between two firms' knowledge stock. We operationalize it based on the similarities between the two firm's patent stocks. The patent data is following previous methods, we calculate technological proximity based on Jaffe distance (Jaffe, Trajtenberg, and Henderson 1993):

$$TP = \frac{\sum_{k=1}^{n} x_{ik} x_{jk}}{\sqrt{\sum_{k=1}^{n} x_{ik}^2 \sum_{k=1}^{n} x_{jk}^2}}$$

Where k is the number of classification of patents, x_{ik} and x_{jk} are the ratio of the number of patents generated by i and j in the kth class to the total number of patents generated by firm i and j.

4.2.5 Controls

We control for a range of variables that might matter for network alliance and blockchain application. We include *R&D intensity*, and we control for *Firm Size* and *Firm Age*. *R&D intensity* is measured as the log value of the average R&D investment per person. Firm size is measured by the log value of the firms' total assets. Firm age is measured as the log value of the number of years since the year the firm listed, as older firms may have more established channels and approaches in adopting blockchain technology. We control for Tobin's Q ratio (*TobinQ*), since firms that have more market value are more likely to spend more on new technologies (Arena et al., 2018). We also controlled for the ownership of the firm, the variable *State-owned* is 1 if the firm is state-owned, and 0 if it is not.

4.3 SAOM and SIENA

In this paper, stochastic actor-oriented model (SAOM) is employed to investigate the formation and evolution of supply chain network. SAOM is a statistical methodology for the analysis of longitudinal network data, which is appropriate for analyzing panel data of supply chain network. Because the supplier–customer relationship between firms may be established, retained or terminated at the different time points, which means that the composition changes over time. SAOM is implemented in the *RSiena package* in R, which stands for Simulation Investigation for Empirical Network Analysis (SIENA) (Snijders et al. 2024). There is a wide body of literature on supply chain network, fewer have used SAOM, with few exceptions (Adaryani et al. 2023).

SAOM regards individual nodes (firms) as actors that form, maintain, and/or dissolve supplier–customer ties rely on the existing network structure and the characteristics and behavior of ego and alters (Snijders, van de Bunt, and Steglich 2010) (Kalish 2020; Snijders et al. 2010). Therefore, the network evolution depends on the combination of two random processes: opportunities for change and options for change (Snijders 2017). The SAOM utilizes Markov chain Monte Carlo methods based on the method of moments to simulate the parametric estimation of models for endogenous network structural effects, exogenous dyadic effects of pairs of firms, and individual characteristics of firms (Snijders 2001). More specifically, the SAOM are based on the following three basic assumptions (Adaryani et al. 2023; Balland, De Vaan, and Boschma 2013; Snijders et al. 2010): (i) the network evolution is a Markov chain process, which implies that the network structure at time $t+1$ only relies on the state of the network at time t. (ii) the underlying time parameter between observations is continuous, which implies that the observed change is the outcome of an unobserved series of micro steps. (iii) the actors control and change their outgoing ties on the basis of their attributes, their position in the network, and their preferences, using the term ‘actor-based model’. For more technical information see Snijders et al (2010), Snijders (2017) and Snijders et al (2024).

The supply chain network is a directed network, sender actors are *ego*, and receiver actors are *alter*. Hence, we model the creation and maintenance of ties using modelType = 1, which is used for directed networks. The network evolution is described as two functions: the first is *rate function*, which is applied to determine the opportunities of relational change. The second is *objective function*, actors decide to create and maintain ties by maximizing their objective function. We estimate the following equation:

$$P\left\{X(t)-x^0\right\} = p_i\left(x^0, x, v_i, w_{ij}\right) = \frac{\exp\left(f_i(x^0, x, v_i, w_{ij})\right)}{\sum_{x\in C\left(x^0\right)} \exp\left(f_i(x^0, x, v_i, w_{ij})\right)} \qquad (1)$$

The objective function (f_i) describes actors' preferences and constraints, which is a linear combination of effects, relying on the current state (x^0), the potential new state (x), individual characteristics (v) and dyadic characteristics of pairs (w), by estimating the following equation:

$$f_i(x^0, x, v_i, w_{ij}) = \sum_k \beta_k S_{ik}(x^0, x, v_i, w_{ij}) \qquad (2)$$

Where $S_{ik}(x^0,x,v_i,w_{ij})$ represents objective function, β_k represents the parameters of the objective function.

As suggested by manual for Rsiena (Snijders et al. 2024), reciprocity effect and out-degree (density effect) must be included into the model. The reciprocity is the fraction of ties in the network that are reciprocated over the total number of ties, which models the tendency to reciprocate incoming ties (Li, Krackhardt, and Niezink 2023). In a supply chain network setting, a higher level of reciprocity means that the relationship formed between two supply chain actor is of a greater importance, and a higher level of mutual trust. The out-degree effect (density effect) is defined by the outgoing ties of the firm, to control for the density in the network. Following prior studies, we mean-centered the interaction terms before the analysis to avoid possible collinearity issue (Kalish 2020; Zhou et al. 2014). We present the summary statistics and correlations in Table 2 and 3.

Table 2 Summary Statistics

Variable	Mean	SD	Min	Median	Max
Supply chain alliance (SCA)	0.000	0.005	0.000	0	1
Blockchain application	0.329	2.561	0.000	0.000	95.000
Geographical proximity	0.004	0.024	0.000	0.001	1.000
Technological proximity	0.157	0.354	0.000	0.000	1.000
Firm size	21.232	3.243	14.941	22.073	31.036
Tobin Q	1.538	1.917	0.000	1.271	44.005
Firm age (ln)	2.029	1.126	0.000	2.303	3.401
State owned	0.316	0.465	0.000	0	1
R&D intensity	14.350	7.474	0.000	0	23.810

Table 3 Correlations

		1	2	3	4	5	6	7	8	9
1	Supply chain alliance		0.000	0.002**	0.001**	-0.002**	-0.002**	-0.002**	-0.001**	-0.002**
2	Blockchain application	0.000*		0.080**	0.002**	0.103**	0.140**	0.089**	0.006**	0.149**
3	Geographical proximity	0.001**	0.015**		0.273**	0.401**	0.397**	0.386**	0.162**	0.414**
4	Technological proximity	0.001**	0.004**	0.039**		0.212**	0.131**	0.125**	0.096**	0.247**
5	Firm size	-0.003**	0.064**	0.076**	0.228**		0.218**	0.676**	0.448**	0.772**
6	Tobin Q	-0.001**	0.049**	0.038**	0.074**	0.449**		0.386**	0.063**	0.410**
7	Firm age	-0.003**	0.064**	0.063**	0.172**	0.866**	0.415**		0.539**	0.517**
8	Stateowned	-0.001**	-0.013**	0.026**	0.098**	0.358**	0.069**	0.478**		0.280**
9	R&D intensity	-0.002**	0.068**	0.076**	0.241**	0.584**	0.459**	0.835**	0.323**	

Notes: Pearson correlations are below the diagonal; Spearman correlations are above the diagonal. $* p < 0.05$; $** p < 0.01$; $*** p < 0.001$.

5. Results

5.1 Analysis results

The results of the SAOM are reported in Table 4. All parameter estimations in our model are based on 5000 iterations. The overall maximum convergence ratio is less than 0.2, and all the individual parameters have the absolute value of the convergence t-ratio less than 0.1, suggesting that the mode convergence is good, and the estimation is valid. The significant effect of reciprocity (β = 3.757, p = 0.000) suggests that once the alliance is built, there is an obvious bilateral interaction between the two supply chain actors. The coefficient of outdegree effect (β = -3.903, p = 0.000) is significantly negative, which suggests that there is a low probability of befriending arbitrary others (Snijders 2017).

Hypothesis 1 proposes that the blockchain application could facilitate supply chain alliance. The coefficient of constant supply chain alliance (SCA) rates in Table 4 suggests that the alliance between supplier and customer is changing every year, and that such change is significantly different from zero. These results indicate that supply chain alliance is dynamic in nature, and the supply chain network is evolving through time (Ahuja, Soda, and Zaheer 2012). Under this condition, the coefficient of the blockchain application is positive and statistically significant (β = 0.624, p = 0.001), suggesting that blockchain application has a positive effect on the formation and maintenance of supply chain alliance. This result is in line with the recent empirical studies on blockchain application, which shows that blockchain technology improves agri-food supply chain processes by evolving organization capabilities (Sharma et al. 2023). Therefore, Hypothesis 1 is supported.

Hypothesis 2 argues that the positive effect of the blockchain application is moderated by geographic proximity. Table 3 shows that the coefficient of the interaction variable has a positive sign and is significant (β = 1.782, p = 0.000), meaning that the geographical proximity positively moderates the relationship between blockchain application and supply chain alliance. This result is in accordance with prior conceptual studies which point out the important role of geographical dispersion of supply chain in shaping the impacts of blockchain application (Ahmed et al. 2022). Therefore, Hypothesis 2 is supported.

Hypothesis 3 assumes that technological proximity positively moderates the relationship between blockchain application and supply chain alliance. The interaction term between blockchain application and technology proximity has a positive and statistically significant effect (β = 0.140, p = 0.000), implying that the creation and persistence of a supplier–customer tie between two firms is more likely if they use blockchain technology and are cognitively proximate at the same time. Therefore, Hypothesis 3 is confirmed.

Table 4 Regression results using SAOM

	Estimate	Standard error	t-value	p-value	95% CI
Network dynamics					
Constant SCA rate (period 1)	0. 828***	0. 039	21.50	0.000	[2.120, 2.471]
Constant SCA rate (period 2)	0. 664***	0. 035	19.10	0.000	[1. 814, 2.080]
Constant SCA rate (period 3)	0. 486***	0.024	19.84	0000	[1. 551, 1.704]
Constant SCA rate (period 4)	0. 557***	0.032	17.48	0.000	[1. 639, 1.858]
Constant SCA rate (period 5)	0. 443***	0.022	20.47	0.000	[1. 492, 1.626]
Constant SCA rate (period 6)	0. 428***	0.023	18.96	0.000	[1. 467, 1.605]
Constant SCA rate (period 7)	0. 384***	0.021	18.27	0.000	[1. 409, 1.530]
Constant SCA rate (period 8)	0. 393***	0.021	18.78	0000	[1.421, 1.544]
Reciprocity	3.757***	0.285	13.18	0.000	[24.494, 74.858]
Outdegree (density)	-3.903***	0.125	-31.24	0.000	[0.016,0.026]
Blockchain application	0.624**	0.192	3.26	0.001	[0.426, 0.843]
Blockchain application # Geographical proximity	1.782***	0.303	5.87	0.000	[3.335, 10.816]
Blockchain application # Technological proximity	0.140***	0.036	3.85	0.000	[1.072, 1.234]
Geographical proximity	1.338**	0.476	2.81	0.005	[1.499, 9.689]
Technological proximity	0.067**	0.032	2.09	0. 036	[1.004, 1.139]
Controls					
Firm size	-0.027**	0.010	-2.68	0.007	[0.954, 0.993]
Firm age	-0.014	0.075	-0.18	0.854	[0.851, 1.142]
R&D intensity	0.050	0.083	0.60	0.545	[0.926, 1.267]
Tobin Q	0.000	0.007	-0.01	0.988	[0.986, 1.014]
State owned	-0.762***	0.121	-6.30	0.000	[0.368, 0.592]

Notes: All convergence t ratios < 0.1. Overall maximum convergence ratio 0.2. The table reports the estimated coefficients of SAOM method (supply chain alliances) based on 5000 times of simulation. $*p < 0.05$; $**p < 0.01$; $***p < 0.001$. CI is confidence interval.

5.2 Robustness checks

We use alternative means to measure the variables to test the robustness of our results. We choose to use the ratio of blockchain related sentences to the number of all sentences in the annual report of listed firms, *BCratio,* to replace the original measurement of blockchain application. *BCratio* measures the extent to which the firm incline to invest in and adopt blockchain technology. The alternative measurement ranges from 0 to 1, a higher score means that the firm is more inclined to use blockchain technology.

Further, we use traditional logistic regression model as the alternative analysis model, to predict the formation of supply chain alliance. Considering the high volume of data, we only choose the records from 2018 to 2020 to test the model's robustness. The three-year subsample contains 27543985 observations. Before the analysis, we also calculated the VIF and joint significance value of the variables. The VIF value is 4.86, which is significantly lower than the threshold value 10. And the joint significance test is also positive ($F(8, 27543976) = 45.03^{***}$). Table 5 shows the results of the robustness analysis. As shown in Models 1 to 5, the relationship between blockchain application and supply chain alliance remains positive, which is consistent with prior analysis. When the interaction terms between blockchain application and the two moderators were added in Models 3 and 4 respectively, the moderating effects of both geographical proximity and technological proximity are consistent with outcomes reported in previous research. Finally, the results in Model 5 are materially unchanged compared to original results.

Table 5 Robustness Check using logistic regression and alternative measurement of blockchain application

SCA 2018-2020	1		2		3		4		5	
Firm size	-0.067**	(-2.082)	-0.069**	(-2.134)	-0.069**	(-2.152)	-0.057*	(-1.772)	-0.057*	(-1.783)
Tobin Q	-0.007	(-0.180)	-0.005	(-0.139)	-0.006	(-0.169)	0.006	(0.175)	0.005	(0.142)
Firm age	-0.509***	(-7.888)	-0.504***	(-7.818)	-0.502***	(-7.789)	-0.486***	(-7.475)	-0.484***	(-7.452)
State-owned	0.505***	(4.737)	0.498***	(4.668)	0.493***	(4.626)	0.469***	(4.382)	0.465***	(4.350)
R&D intensity	0.085**	(2.252)	0.088**	(2.313)	0.087**	(2.284)	0.059	(1.562)	0.058	(1.532)
Blockchain application			2.294***	(3.561)	2.721***	(5.516)	2.946***	(7.651)	1.873***	(4.15)
Blockchain application #					1.838***	(7.865)			1.422***	(13.022)
Geographical proximity										
Geographical proximity					0.341***	(6.311)			0.177***	(5.367)
Blockchain application							0.165**	(2.24)	0.145***	(3.668)
#Technology proximity										
Technology proximity							0.103**	(2.505)	0.027**	(2.27)
Constant	-9.823***	(-173.932)	-9.823***	(-173.930)	-9.825***	(-173.963)	-9.844***	(-173.857)	-9.846***	(-173.875)
Observations	27543985		27543985		27543985		27543985		27543985	
R square	0.0126		0.0128		0.0146		0.0164		0.0179	

z statistics in the parenthesis, $*\ p < 0.05$; $**\ p < 0.01$; $***\ p < 0.001$.

6. Discussion

This investigation delves into the impact of blockchain applications by firms on the formation of alliances within the supply chain network. A longitudinal analysis of Chinese-listed firms, employing a SAOM, reveals a positive impact of blockchain application on the formation of alliances within the supply chain. Notably, our study indicates that this impact is strengthened by both geographical and technological proximities. In turn, this study collocates within the literature by addressing the limited understanding of blockchain's role in shaping network dynamics and alliance formation. Moreover, it also shows how geographical and technological proximity amplify blockchain's impact on alliance formation, extending the prior operational focus of blockchain studies with a more nuanced understanding.

6.1 Theoretical implications

Firstly, our study advances blockchain application research by elucidating how blockchain technology impacts the formation and maintenance of supply chain alliances, addressing an underexplored area in the literature. Prior research has predominantly focused on blockchain's role in enhancing transparency, data visibility, and operational efficiency (Pun et al., 2021; Wang et al., 2018); however, our study contributes a novel theoretical framework examining blockchain's influence on alliance dynamics, particularly at the dyadic level within supply chains. Our research addresses blockchain's contrasting effects, where some studies highlight its transparency and traceability benefits in supply chains (e.g., Pun et al., 2021), while others note limitations such as high energy consumption, scalability issues, and data privacy risks, which can deter adoption and raise ethical concerns among partners, especially in alliances with high sustainability standards. We find that blockchain fosters interorganizational trust—an essential factor for alliance formation—through its self-policing and transparency-enhancing mechanisms, reducing the need for extensive trust-building efforts (Gupta, 2017; Cui et al., 2023).

Additionally, our study identifies contextual factors that enhance blockchain's alliance-forming benefits, such as geographical and technological proximity. The theorization of the two moderators highlights the contextual issues of blockchain application, which generates novel insights that delineates the dynamic relationship between blockchain application and supply chain alliances. Geographical proximity strengthens trust and resource sharing by fostering collaboration efficiency (Chen et al., 2023; Huang & Fan, 2022), while technological alignment eases blockchain integration and adoption by reducing learning and communication barriers (Belchior et al., 2021). Unlike prior studies that treat proximities as direct drivers of alliance formation, these insights into the amplifying effects of proximities as moderators provide a nuanced understanding of how firm-level characteristics shape alliance-building outcomes, addressing calls for research on contextual influences in blockchain applications (Ahmed et al., 2022). Collectively, our study frames blockchain as more than a data-sharing tool; it is a mechanism that enables robust, trust-based alliances, aligning partners with industry standards essential for sustainable supply chain networks.

Secondly, this study extends the alliance literature by examining the contextual effects of geographical and technological proximity on supply chain alliance formation. Prior studies considering the role of between-form proximities focus on its direct impacts, especially in shaping network alliance. For example, prior studies have found that alliance formation likelihood decreases with geographic distance (Reuer and Lahiri 2014); and that different proximities can substitute for or moderate each other (Christoffersen 2013; Erutg et al. 2022). These studies, however, miss the opportunity to investigate the moderating role of proximities in alliance formation, while holds significant theoretical implications. Diverging from this approach, our study empirically demonstrates and theoretically explains the interactive effects of firm-level factors within the supply chain network (Rothaermel and Boeker 2008).

Our findings suggest that the similarities in geographical location and knowledge stock between firms can influence supply chain alliances by impacting trust-building and knowledge sharing, shaping collaboration patterns between supply chain partners. It is noteworthy that although many studies suggest that geographical proximity may have limited impact given advances in information technologies; our study identifies trust-building as a fundamental mechanism affecting the extent to which technology applications foster better collaboration outcomes. In this context, our findings highlight the importance of geographical distance in building trust and enhancing supply chain collaborations, supporting prior studies that underscores this role (Bönte 2008; Wiengarten and Ambrose 2017). Specifically, in our study, geographical proximity does not directly drive alliance formation; instead, it serves as a contextual factor that amplifies the interorganizational trust benefits enabled by blockchain application. As we delineate, geographical proximity facilitates information and tacit knowledge exchange among supply chain actors, and promotes resource sharing and operational efficiency between them. These impacts all contribute to the trust-building process among supply chain actors, amplifying the effectiveness of blockchain application on building and maintaining supply chain alliance.

Meanwhile, technological proximity enhances knowledge sharing and communication between supply chain partners, leading to stronger trust-building and more collaborations. This is because when two firms are technologically close in the supply chain, their information structure would have a higher level of interoperability (Belchior et al. 2021), which accentuates the role of smart contract in facilitating alliances. Thus, while blockchain supports trust-building in supply chains, contextual factors like geographical and technological proximity are essential to fully realize these effects. This delineation of the moderating roles of proximities enriches prior alliance studies on the importance of contextual factors and deepen the understanding of alliance dynamics within unique network contexts, such as supply chains, distinct from other types of networks like knowledge networks (Phene and Tallman 2014).

6.2 Practical implications

This study provides practical implications. Firstly, we emphasize the importance of managing the impacts of blockchain application in a network perspective (Park, Bellamy, and Basole 2018; Queiroz et al. 2019), especially in securing supply chain alliance. With the high cost in adopting blockchain technology (van Hoek 2019), it is important for the managers to understand how the benefits of blockchain application could be leveraged effectively, to generate an overall positive and effective outcome from applying blockchain technology. Given that the impacts of blockchain application could be extended to different aspects of business operation such as product development, business process and customer management, a natural move is to boost the firm’s collaborations with the enhanced interorganizational trust brought by blockchain application. For example, Huawei doubled down on blockchain technology a few years ago to provide blockchain services for a wide range of customers from government to private sectors (Le 2021). Consequently, Huawei accumulated substantial experiences and credibility for providing blockchain services, which contribute to its alliance later with overseas Web3 firms for future business collaborations (Zuo 2023). Therefore, managers should closely examine the possible impacts of blockchain application in the firm's engagement with other firms in the supply chain network and leverage the benefits of blockchain application for better alliance outcomes.

Secondly, we suggest managers build monitoring mechanisms based on the characteristics of external partner, to secure the effectiveness of blockchain applications. Paying attention to the similarity and relatedness between the focal firm and the firm's possible partners is essential in recruiting compatible supply chain partners for effective supply chain collaborations (Boschma 2005; Ertug et al. 2022). Studies pointed out the importance of contextual and temporal factor, as such factors could alter the impacts of blockchain application significantly (Kewell et al. 2017; Rousseau and Fried 2001). For example, prior studies indicated that many blockchain use-cases have encountered the problem of geographical distance, as geographical dispersion of the supply chain increases as the supply chain network expands (Ahmed et al. 2022). In this paper, we suggest that managers keep in mind the differences in geographical locations, physical environment, and technological knowledge stock, which all could greatly change the effectiveness of blockchain application. For example, managers should first consider the cost in terms of logistics, interorganizational learning, before predicting the benefits of blockchain application on supply chain alliance. Based on our findings, we suggest managers working with potential partners in vicinity build a higher mutual trust and share certain resources to reduce the cost in supply chain alliance. Moreover, it is also suggested to recruit partners that have a similar technological mindset, which could greatly lower the bar for effective communication and collaboration.

6.3 Limitations and future research directions

Our research delineates two intrinsic limitations warranting scholarly consideration. Firstly, our analysis of contingency is confined to the dyadic level, presenting an opportunity for future research to extend this analysis to both the broader context of the entire supply chain and the granularity of the individual level. By broadening the scope, researchers can obtain a more comprehensive understanding of the dynamics and interdependencies across different levels within the supply chain network (Chen and Paulraj 2004).

Secondly, it is essential to acknowledge that our research primarily centers on a Chinese setting. To enhance the robustness and generalizability of our findings, future research could incorporate a comparative analysis involving diverse regions. By conducting cross-regional comparisons, researchers can discern nuanced variations influenced by geographical, cultural, and contextual factors (Schuenemann, Katenka, and Ribberink 2023). This approach will not only contribute to the validation of our study but also yield insights into the broader applicability of our findings in diverse global contexts.

Thirdly, we acknowledge that the impacts of geographical proximity on the relationship between blockchain adoption and supply chain alliances, may not apply equally across all contexts. Although physical proximity can enhance trust-building and improve operational efficiency, its impact may vary depending on the type of supply chain. For instance, in more digitized or globalized supply chains, where firms rely less on face-to-face interactions, the transparency and real-time data-sharing capabilities of blockchain technology may reduce the importance of geographical closeness. As a result, the role of geographical proximity might be less significant in these scenarios. Future studies should investigate this hypothesis across various industries and supply chain models, particularly those that are more digital in nature, where physical distance is less of a barrier.

7. Conclusion

To summarize, this research highlights how blockchain technology affects the formation of supply chain alliances, particularly between individual firms. By adopting blockchain, companies can improve transparency, build trust, and enhance operational efficiency, which ultimately strengthens their partnerships. However, our findings reveal that the effectiveness of blockchain varies depending on the context, with geographical and technological proximity playing key roles in amplifying its impact on alliance formation. Nonetheless, the focus on Chinese firms and dyadic relationships suggests that future studies could benefit from examining other regions and levels of analysis, such as entire supply chains or individual actors. Additionally, further work is needed to explore how blockchain interacts with different contextual factors, especially in globalized and digital supply chains where physical proximity may be less relevant. In conclusion, this research enhances the understanding of blockchain applications in supply chains, and initiates discussions on theorizing contextuality in terms of differences in geography and knowledge stock, contributing to a more thorough management debate.

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