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Exploring Supply Chain Capabilities as Drivers for Willingness to Adopt Blockchain Technology Using a Technology–Organization–Environment (TOE) Framework

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Abstract

As blockchain technology reshapes operations and supply chain management (OSCM), understanding its capability-driven adoption pathways is crucial for enhancing supply chain efficiency, resilience, and decision-making. This study applies Fuzzy-Set Qualitative Comparative Analysis (fsQCA) within the Technology-Organization-Environment (TOE) framework to analyze data from supply chain managers with blockchain implementation experience. Our findings reveal three adoption pathways: (1) Dynamic Collaborators, who integrate blockchain through external collaboration and agility; (2) Resilient Specialists, who prioritize internal resilience over partnerships; and (3) Proficient Collaborators, who emphasize information sharing and agility without deep IT integration. These results highlight the causal complexity of blockchain adoption, demonstrating that firms follow multiple strategic configurations based on their capability portfolios. By uncovering scalable, context-specific adoption pathways, this study provides actionable insights for managers and policymakers, advancing both blockchain integration strategies and the broader OSCM literature.

Keywords

Blockchain, supply chain capabilities, fsQCA, agility, resilience, information sharing, TOE

* *The authors report there are no competing interests to declare*.

1. Introduction

The adoption of new technologies has become a key source of competitive advantage across supply chains. For instance, Walmart's adoption of Radio Frequency Identification (RFID) technology revolutionized its inventory management, while Maersk's implementation of blockchain technology streamlined shipping documentation. Blockchain technology -a distributed ledger that records transactions immutably, which improves traceability and trust among supply chain (SC) partners (Queiroz and Fosso Wamba, 2019)- has specifically attracted attention for its ability to provide transparency and security in SCs. With its decentralized and immutable nature, it offers unique advantages that distinguish it from other technological innovations. These benefits render blockchain a promising solution for addressing SC problems such as fraud and inefficiency, improving SC visibility, and enhancing the overall efficacy of SC transactions.

The current body of research considers both firm characteristics and the benefits of, as well as the barriers to, blockchain adoption. However, limited attention has been given to the role of firm-level capabilities, particularly their static and dynamic dimensions, in driving the adoption. By contrast, in this paper, we analyze firms' static capabilities and dynamic capabilities (DCs) using the Technology–Organization–Environment (TOE) framework that incorporates perceptions and characteristics to explain firms' willingness to adopt new technologies from a DCs perspective. The TOE model states that a firm's intention to adopt new technology is influenced by an open array of technological (Xu et al., 2024), organizational, and environmental factors that vary depending on the industry and business environment (Tornatsky and Fleischer, 1990). This framework has been applied to an array of technologies, including Enterprise Resource Planning (ERP), RFID, and blockchain technologies. Nonetheless, previous studies have not incorporated firms' SC capabilities, which provide a foundation on which firms can adopt or confidently explore new technologies. This research gap is critical as these capabilities provide a foundation for firms to adopt or explore new technologies (Sauer et al., 2024).

SC capabilities are broadly defined as the abilities of an organization to effectively and efficiently manage and adapt its SC processes, resources, and relationships to achieve strategic goals and remain competitive (Teece et al. 1997, Winter 2003). Capabilities take time to develop and are fundamental to the willingness to adopt technology for SCs. For instance, relational capabilities such as collaboration foster continuous innovation in SCs (Soosay et al., 2008; Fawcett et al., 2012; Baker, 2012). Information capabilities, including information sharing, enhance intra- and inter-organizational learning during the innovation process (Ruel et al., 2013). DCs, such as agility, improve innovation performance by enabling firms to interact effectively with the external environment (Aslam et al., 2024).

Some literature has begun to incorporate capabilities in technology adoption. For example, Duan et al. (2022) emphasize the importance of information sharing in SC finance, while Zhu et al. (2006) highlight the role of employee communication and flexibility in innovation assimilation. Xu et al. (2024) include flexibility, agility, SC redesign, and risk management culture as factors that impact SC resilience. Specifically, regarding blockchain, Queiroz and Fosso Wamba (2019) highlighted the role of organizational and environmental facilitating conditions in blockchain adoption. Guan et al. (2023) demonstrate that SC factors, such as information sharing and collaboration, influence the willingness to adopt blockchain. However, they do not comprehensively analyze blockchain adoption from a capabilities perspective, as we do below.

Against this backdrop, the purpose of this study is to explore how firm capabilities—both static and dynamic—shape firms' willingness to adopt blockchain technology in SCs, using the TOE framework to identify the configurations of capabilities influencing adoption. To this end, the central research questions guiding this study are: *What firm capabilities, or lack thereof, lead firms to consider adopting new technology? How can different configurations of capabilities be identified to understand their influence on willingness to adopt blockchain?* In this study, we represent the three aspects of the TOE framework through SC capabilities: technological capabilities are represented by firms' information sharing and information integration capabilities; organizational capabilities are represented by external collaboration and communication quality; and the DCs of resilience and agility represent environmental capabilities. We examine the impact of these TOE factors on firms' willingness to adopt blockchain technology within the SC. SC managers can further develop such capabilities within the firm and across SC partners by understanding which SC capabilities precede potential blockchain adoption.

This paper introduces a novel approach using Fuzzy-Set Qualitative Comparative Analysis (fsQCA) to address the complexity and multifaceted nature of willingness to adopt blockchain technology. The reason for using fsQCA is its strength in handling complex, causal relationships and identifying different typologies or combinations of conditions that lead to an outcome. Unlike traditional methods such as structural equation modeling (SEM), which may oversimplify the relationships by focusing on linear correlations, fsQCA allows for examining how multiple factors interact in different configurations to influence willingness to adopt the technology. This method is particularly suited for identifying diverse pathways that firms may take based on their unique sets of capabilities, providing a richer and more nuanced understanding of the determinants of willingness to adopt technology.

2. Literature review

2.1. Summary of blockchain in supply chain management

There are SC benefits from blockchain adoption. Blockchain enhances data transparency and integrity in supply chain management (SCM) (Queiroz et al. 2020), which is especially crucial for operations involving upper-tier suppliers. Fostering a consensus-based ledger system enables a shared version of the truth that is essential for inter-organizational information sharing, thus addressing the perennial challenges of visibility in SCs (Gligor et al., 2022b; Xu and He, 2024). The indelible nature of blockchain's transaction logs provides an indispensable audit trail for sectors requiring stringent traceability (Behnke and Janssen, 2020).

Multiple factors prepare SCs to adopt blockchain. Balasubramanian et al. (2021) assess blockchain adoption readiness through motivational, engagement, technological, and structural dimensions. Supplementing this, social capital theory examines blockchain adoption through relational, cognitive, and structural capital within networks, emphasizing trust and shared goals (Galati, 2022). Technology readiness and affinity -the preparedness and propensity to use blockchain- and facilitating conditions, such as users' perceptions and support availability, have also been shown to lead to blockchain adoption (Wong et al., 2020). Analyzing the blockchain adoption literature, Zhang et al. (2024) show that the need to improve traceability, improve operations, or respond to pressure from stakeholders positions companies to adopt blockchain for SCs, considering inter/intra-organizational and external factors.

Contrastingly, blockchain's adoption is impeded by factors such as technological unfamiliarity, regulatory uncertainty, and implementation complexity, which can be daunting for firms considering large-scale SC integrations (Mathivathanan et al., 2021). Overcoming these barriers requires a nuanced understanding of the technology and the multifactorial ecosystem influencing willingness to adopt blockchain SCM.

Some scholars have utilized the TOE framework to understand blockchain adoption due to its tractability and scope. Malik et al. (2021) examine blockchain adoption in Australia from the perspective of information transparency and disintermediation, organization innovativeness, organizational learning capability, standards uncertainty, and perceived risks, addressing only one organizational, rather than SC, capability. Ganguly (2024) explores blockchain adoption in the logistics sector, looking at infrastructure, organizational resources, government regulation, complexity, organizational innovativeness, customer, compatibility, internal stakeholder, competitor, risk, organizational size, and location, overlooking capabilities altogether. Chittipaka et al. (2023) surveyed SC managers in India, finding that all of their TOE constructs, including relative advantage, trust, compatibility, security, firm's IT resources, higher authority support, firm size, monetary resources, rivalry pressure, business partner pressure, and regulatory pressure, significantly influence the decision of blockchain technology adoption. Such studies show how SC characteristics and status impact blockchain, but no capability measures are employed.

Based on this overview, we find that the existing blockchain literature fails to address the specific capability drivers that shape the willingness to adopt blockchain. Our paper makes a unique contribution by integrating these capability categories within the TOE framework to explain blockchain adoption, as follows.

2.2. Capability drivers of willingness to adopt blockchain

SC capabilities are more complex and, in some ways, more intentional than SC characteristics. SC capabilities are defined by firms' abilities to recognize, assimilate, and utilize resources and information to facilitate SC activities effectively (Wu et al., 2006). These capabilities catalyze value creation within inter-firm relationships and enhance overall firm performance. While blockchain adoption has been recognized to enhance capabilities such as traceability, visibility, and adaptability, as well as sensing, seizing, and reconfiguring DCs (Meier et al., 2023; Quayson et al., 2023), capability drivers leading to willingness to adopt blockchain have yet to be explored.

In the context of willingness to adopt blockchain, we focus on three pivotal *SC capabilities: relational, information, and dynamic*, which represent, respectively, the organizational, technological, and environmental aspects of willingness to adopt technology. The TOE framework provides a lens through which to view these capabilities, which are intrinsically linked to blockchain's potential and prerequisites. Blockchain's nature as a complex, multifaceted technology necessitates a foundational level of information technology infrastructure and proficiency, well-established relationships among SC partners, and a certain degree of organizational agility and resilience in various configurations. Firms well-versed in these capabilities are poised to overcome the barriers to adopting blockchain, including technological challenges, human resource limitations, organizational inertia, and broader social and environmental concerns (Ozturk and Yildizbasi, 2020). In the subsequent sections, we explore how relational, information, and DCs facilitate the willingness to adopt blockchain to streamline SC operations.

Figure 1 illustrates the relationship between information, relational, and DCs within the TOE framework and the willingness to adopt blockchain. Relational capabilities include collaboration and communication quality. Information capabilities include information sharing, exchange, and integration. DCs include agility and resilience. In the next section, we discuss these capabilities listed in the subcategories and their impact on willingness to adopt blockchain.

Figure 1 Here

2.2.1 Technology: Information capability drivers of willingness to adopt blockchain

Technology is represented by informational capabilities, as these form the basis for technological functioning. Information capabilities are critical in technology adoption, as they enable SC partners to harness data as a strategic asset. These capabilities facilitate the sharing and integration of information, which is fundamental to firms' competitive positioning in dynamic markets. The strategic response to market changes, bolstered by these capabilities, can lead to faster innovation, improved customer responsiveness, and enhanced SC performance (Gu, Yang, and Huo, 2021).

2.2.1.1. information sharing. Information sharing is disseminating critical SC data and enhancing visibility and coordination among partners (Zhao, Droge, and Stank, 2001). This capability is central to mitigating distortions, such as the bullwhip effect, and fostering collaborative advantages (Chen et al., 2019). With its transparent and decentralized ledger, blockchain relies on the principle of shared information to resolve trust and transparency issues within SCs (Gligor et al., 2022b). Firms with established practices of transparent information sharing are more likely to recognize the benefits of blockchain and be poised for its adoption (Agi and Jha, 2022).

Despite the presence of these studies, the role of information sharing as a precursor to blockchain adoption remains underexplored, especially within the fsQCA method, which allows for more than one outcome. Importantly, given the scarcity of studies exploring willingness to adopt blockchain, in line with fsQCA theory development guidelines (e.g., Gligor and Bozkurt, 2020a; Woodside et al., 2012) we do not speculate as to whether it is the absence or presence of information sharing that contributes to firms' willingness to adopt blockchain. Rather, we acknowledge that, under different scenarios (i.e., the presence or absence of other factors), both scenarios could lead to a willingness to adopt blockchain (Pappas and Woodside, 2021). Thus, our objective is to uncover those scenarios rather than seeking to conclude that a positive or negative relationship exists between the two concepts (see Woodside, 2013).

2.2.1.2. Information integration. Information integration extends the concept of sharing by combining data from multiple sources into a cohesive, unified system. It enables a comprehensive view of the SC, facilitating strategic responses and effective supply-demand balance (Thun, 2010). This capability is distinguished from information sharing by its focus on harmonizing data to ensure seamless flow and integration. Information integration, encompassing both internal and external dimensions, enhances the visibility of the SC network (Huo et al., 2014). As blockchain technology benefits from integrated information systems, firms with advanced information integration capabilities are well-positioned to adopt blockchain. Such integration ensures that the distributed ledger operates effectively, leveraging the technology's strength to provide a transparent, real-time view of transactions. While previous research has emphasized the need for integrated information in SCs, the application of these insights into blockchain adoption frameworks has been limited. We address this gap.

Information sharing and integration create a foundation for transparency and collaborative efficiency, prerequisites for blockchain integration in SCM (Foster, 2023). As such, we propose that they play a role in firms' willingness to adopt blockchain. Consistent with fsQCA principles (Woodside, 2013; Russo et al., 2016), we explore their impact on willingness to adopt blockchain in the context of the presence or absence of other factors, which we discuss next.

2.2.2. Organization: Relational capability drivers of willingness to adopt blockchain

Relational capabilities are fundamental competencies that facilitate managing relationships within SC organizations, as Chen et al. (2004) outlined. These capabilities encompass collaborative communication, knowledge transfer, and strategic use of cross-functional teams to yield competitive advantage. They are fostered through a commitment to mutual trust, coordination, and cooperation, creating unique and difficult-to-imitate capabilities. This collaborative ethos is conducive to adopting blockchain technology as it necessitates a consensus on common goals and procedures among SC partners.

2.2.2.1. External collaboration. External collaboration in the SC, as described by Stank et al. (2001), is the upstream and downstream exchange of operational information, creating an integrated performance measurement system. Cao and Zhang (2011) define it as partnerships that plan and execute SC operations for mutual benefit. Collaborative SCs, which share goals and synchronize decisions, can improve competitive advantages and mitigate risks, as highlighted by Fawcett et al. (2008).

This capability, a precursor to blockchain adoption, has not been previously applied. However, past research showed that external collaboration can influence firms' willingness to adopt new technologies (Bobrowski and Bretschneider, 1994). Further, these relationships are integral for firms aiming to adopt blockchain technology, which demands collaboration on shared objectives and standards (Happy et al., 2023). As such, there are theoretical reasons to consider the influence of external collaboration on firms' willingness to adopt blockchain.

2.2.2.2. Communication quality. The quality of communication in SCs is a foundational relational capability that significantly influences the potential for willingness to adopt blockchain. Elements of customer communication quality—rapid and successful information transmission, reliability, and suitability for problem-solving—are fundamental for establishing trust, transparency, and collaboration (Gligor and Holcomb, 2012).

Past research has proposed that communication quality can play a role in blockchain adoption (Happy et al., 2023). In addition, communication quality enables SC partners to manage relationships, resolve conflicts, and create synergies (Monczka et al., 1998), which are essential for implementing and operating blockchain systems. As such, we explore how and when the presence or absence of communication quality influences firms' willingness to adopt blockchain.

In summary, these relational capabilities—external collaboration and communication quality—are intricately linked to the willingness to adopt blockchain, as illustrated in Figure 1. They provide the essential interpersonal framework that supports the operationalization of blockchain technology, ensuring that SC partners are aligned, and information is exchanged effectively for the successful integration of blockchain into SCM processes.

2.2.3. Environment: Dynamic capability drivers of willingness to adopt blockchain

The environment is represented by the DCs of agility and resilience, as these allow an organization to perform successfully in a turbulent environment (McCann et al., 2009; Lengnick-Hall and Beck, 2016). Teece et al. (1997) define DCs as a company's ability to integrate, build, and reshape competencies to adapt to new circumstances. These DCs manifest in business processes, resource allocations, and the capacity for ongoing transformation (Teece, 2007). They are fundamental for firms aiming to adopt innovative technologies like blockchain, as they enable sensing opportunities, seizing them through resource mobilization and the subsequent transformation of operations to incorporate new technologies.

DCs extend into the realm of SCs, where they facilitate cross-organizational activities that generate new capabilities or enhance existing ones, thus allowing SC partners to capitalize on new opportunities. Developing these capabilities can improve operational and economic performance, granting organizations the agility to adjust their SC structures effectively (Meier et al., 2023). Resilience and agility can be categorized as DCs, as these capabilities are primarily concerned with change and learning (Winter, 2003), and are chosen to represent a SC's environment-oriented capabilities.

2.2.3.1. Supply chain resilience. SC resilience is an aspect of DCs that involves preparing for, responding to, and recovering from disruptions while maintaining operational continuity (Ponomarov and Holcomb, 2009). Scholars such as Christopher and Peck (2004) emphasize the importance of flexibility, collaboration, agility, and risk awareness as key antecedents of SC resilience. Resilient SCs are characterized by their capacity to resist disruptions and recover swiftly, in part due to their flexible and redundant systems (Melnyk et al., 2014).

Recent studies have highlighted that blockchain adoption can positively contribute to SC resilience (Chowdhury et al., 2023; Liu et al., 2024). This suggests that it is plausible for firms to perceive blockchain as a means to enhance their SC resilience. Therefore, firms' respective levels of SC resilience are likely to influence their willingness to adopt blockchain. Specifically, it is plausible that firms that seek to enhance their levels of SC resilience might be more willing to adopt blockchain than firms relatively content with their SC resilience levels. This reasoning offers further impetus for considering the role of SC resilience in our framework.

2.2.3.2. Supply chain agility. SC agility entails rapidly adapting SC tactics and operations in response to environmental changes (Gligor et al., 2014). It encompasses many attributes, including rapid response to supply and demand changes, disruption management, and leveraging changes as opportunities (Gligor, 2014). The literature suggests that agility, supported by human and information technology resources, is critical for the smooth operation of SCs (Ngai et al., 2011).

SC agility has been shown to be influenced by blockchain adoption. Specifically, the adoption of blockchain technology can enhance firms' SC agility (Sheel and Nath, 2019). As such, similar to the effects proposed for SC resilience, it is plausible that firms might perceive blockchain as a solution for improving their SC agility. This reasoning prompts the consideration of SC agility as a factor that should be included in our framework exploring conditions that influence firms' willingness to adopt blockchain.

The research summarized in Table 1 collectively explores the intersection of blockchain with various aspects of SC capabilities, as cited above. Almost none of the capabilities we discuss under the TOE framework have been previously examined as precursors to blockchain adoption. Hence, we fill a significant gap in the blockchain adoption literature in this context.

Table 1 Here

3. Research design

This study investigates the interplay between SC capabilities and the willingness to adopt blockchain technology. Given the exploratory nature of our research and the inherent causal complexity of blockchain adoption, we employ fsQCA as our primary analytical tool. FsQCA is particularly well-suited to understanding complex, real-world phenomena because it accommodates asymmetric relationships and nonlinear interdependencies. It also aligns with the equifinality principle, which posits that multiple configurations of causal factors can lead to the same outcome (Ragin, 2008; Gligor et al., 2022a). These advantages make fsQCA ideal for uncovering the nuanced and ambiguous pathways through which SC capabilities influence blockchain adoption.

3.1 Survey design, participant recruitment, and eligibility

The survey design followed a rigorous development to ensure theoretical robustness and practical relevance. We began with an extensive literature review on blockchain adoption and SC capabilities, identifying key factors influencing adoption decisions. This foundation was enriched through expert interviews with blockchain SC specialists, providing practical insights into real-world challenges and applications. These interviews ensured that the survey items accurately captured the nuances of blockchain adoption in SC contexts, bridging academic theory with industry realities (Khamitov et al., 2020).

The final survey instrument measured six critical SC capabilities: information sharing, external collaboration, information integration, communication quality, resilience, and agility, and their influence on the willingness to adopt blockchain. To facilitate nuanced responses, a 5-point Likert scale (1 = strongly disagree, 5 = strongly agree) was employed. Detailed information about construct measures, their sources, and relevant descriptive statistics can be found in Table A (refer to Supplementary Data Material).

Prior to full deployment, the survey underwent a pilot study involving a small group of SC professionals. This pilot phase ensured the survey items' clarity, neutrality, and practical relevance. Feedback from the pilot study was used to refine the survey instrument, minimizing response bias and validating the overall design for the final study phase.

The final survey was deployed in August 2023 using Prolific, a widely recognized participant recruitment platform frequently employed in academic research. Prolific provides high-quality, diverse participant samples with stringent quality controls, including email validation, IP address monitoring, and demographic cross-referencing. These measures ensured respondents met the study's eligibility criteria, reducing the risk of duplicate or fraudulent responses. Prolific's robust verification protocols provided confidence in the authenticity and quality of the respondent pool (Khamitov et al., 2020).

The target respondents were SC managers, selected for their pivotal role in linking strategic decision-making with operational execution. SC managers possess a unique perspective on organizational strategy and technological implementation, making them key stakeholders in blockchain adoption decisions (Dong et al., 2024).

To ensure eligibility and respondent expertise, participants needed to meet strict criteria: they had to have experience with blockchain technology, either in firms currently using, having previously used, or actively considering blockchain adoption. They were also required to hold managerial roles with decision-making authority in technology adoption and actively engage in SC operations to ensure informed and meaningful responses.

To further validate participant eligibility, manipulation checks were embedded in the survey. Respondents were asked to identify common blockchain applications in SC contexts, such as enhancing data transparency, enabling real-time tracking, and verifying product authenticity (Falcone et al., 2021). Additionally, they were required to recognize blockchain-related challenges, including creating verifiable records, facilitating synchronized communication, and enabling real-time data transmission. These checks ensured that only participants with sufficient contextual understanding and expertise proceeded to complete the main survey.

This systematic approach to survey design, participant recruitment, and validation ensures the theoretical and practical robustness of the study while maintaining data quality and respondent authenticity.

3.2 Data collection and curation

The survey yielded an initial dataset of 429 responses, which underwent a rigorous data-curation process to ensure data integrity and reliability. The cleaning process began with removing 32 responses due to duplicate IP addresses, followed by excluding four suspected bot entries and 11 responses exhibiting uniform patterns, such as repetitive selections across survey items. Additionally, 210 responses were disqualified for failing manipulation checks, which were designed to verify participants' blockchain expertise and understanding of key concepts. These measures ensured that only high-quality, meaningful responses advanced to the analysis stage.

The *final dataset comprised 172 valid responses*, aligning with the sample size norms observed in prior blockchain adoption studies (Arellano et al., 2021; Chowdhury et al., 2023). After the initial filtering, the dataset was further assessed for incorrect coding, missing values, and multicollinearity, revealing no significant issues.

To address potential non-response bias, a paired t-test was conducted in SPSS, comparing responses collected in the early phase and late phase of data collection. The results showed no statistically significant differences, with all p-values exceeding the 0.05 threshold. This analysis indicates that non-response bias was not present, reinforcing the reliability and representativeness of the final dataset.

3.3 Sample characteristics

Table 2 presents the demographic breakdown of the final sample. The respondents represented a diverse range of firm sizes, industries, and ages, ensuring the robustness and generalizability of the findings.

Table 2 Here

3.4. Measure validation and reliability

The reliability of the constructs and scales was confirmed using Cronbach's alpha and composite reliability methods. Table 3 presents these indices, all exceeding the threshold of 0.70, affirming the scales' satisfactory reliability.

Table 3 Here

To evaluate the presence of multicollinearity in the indicators, the variance inflation factor (VIF) is calculated. This measures how each variable is linearly related to others (Hair et al., 1998). The results show that all VIF values are below four, significantly lower than the commonly accepted threshold of 10, suggesting no multicollinearity issues, as Neter et al. (1996) noted. Furthermore, factor loadings for all constructs were higher than the established benchmark of 0.60, demonstrating the convergent validity of the theoretical constructs. Additionally, as shown in Table A, the average variance-extracted (AVE) values for each construct were above the 0.50 mark, as O'Leary-Kelly and Vokurka (1998) suggest for strong convergent validity. The HTMT ratios for all traits were below 0.85, satisfying the stringent criteria for discriminant validity, as illustrated in Table 4.

Table 4 Here

3.5. Assessing endogeneity

An endogeneity test confirms that the outcomes should be interpreted as a correlation rather than causation due to the cross-sectional characteristic of the dataset (Lu et al., 2018). Endogeneity often leads to biased outcomes due to simultaneity or reverse causality. To mitigate this issue, our study employed the Gaussian copula method, which does not rely on instrumental variables (IVs). This approach has been used by other studies in the literature (Patil et al., 2024). This approach, elaborated by Park and Gupta (2012) adhering to Becker et al. (2022) guidelines, offers notable benefits over traditional methods that use IVs to address endogeneity, as discussed by (Sande and Ghosh, 2018)

The Gaussian copula method enhances the accuracy of estimating parameters for endogenous regressors and helps ascertain the impact of endogeneity on a regression model. This is done by examining the copula term's statistical significance, which, if found significant, indicates an endogeneity issue in the empirical study, as explained by (Becker et al., 2022). A significant Gaussian copula term suggests the presence of endogeneity, and its inclusion in the regression model should rectify this issue, according to Rubio-Andrés et al. (2022).

Conversely, if the correlation is not significant, it is presumed that endogeneity does not substantially influence the model's outcomes. Thus, the respective copula terms are excluded from the final model, as Haschka (2021) notes. Our analysis's p-values exceeded 0.05, suggesting the absence of endogeneity concerns. We thoroughly examined the relationships between variables and their combinations, ensuring no p-value was lower than 0.05. Therefore, this study does not pose any endogeneity issues.

3.6. Common method bias (CMB)

In our study, to effectively address common method bias (CMB), we implemented two proactive strategies recommended by Podsakoff et al. (2003). Firstly, we ensured the anonymity of respondents in our survey to foster an environment conducive to genuine responses, thereby reducing the likelihood of responses influenced by social desirability biases. Secondly, we applied two distinct statistical methods to further control for CMB.

The first method involved utilizing Harman's single-factor test. This approach was particularly pertinent given that our data collection relied on a single method. The analysis revealed that the maximum variance attributable to any single factor was only 36.48%, comfortably below the 50% threshold posited by Podsakoff et al. (2003). This result suggested the absence of a dominant factor in the data, implying that no single factor significantly skewed the results. Consequently, this indicated a minimal impact of common method bias on our study's findings.

To reinforce our assessment, we also incorporated the procedure recommended by Liang et al. (2007) for calculating common factor loadings. The analysis revealed a critical insight: while the loadings for the proposed constructs were notably significant, the common loadings lacked similar significance. This discrepancy further validated our conclusion that common method bias did not significantly threaten our research findings.

4. Fuzzy-set qualitative comparative analysis (fsQCA)

Scholars have underscored the complexity of decision-making using traditional statistical analysis, leading to limited results that translate to real-world relevance, as shown by Gligor et al. (2022a). We incorporated the fsQCA (Ragin, 2008) in response to the call for novel methodologies by Mithas et al. (2022). Our research question focuses on understanding the combination of SC capabilities that drive SC managers' willingness towards blockchain.

Blockchain adoption in SCs often involves ambiguity and uncertainty due to the diversity of organizational capabilities and contextual influences. These factors create causal complexity that cannot be captured effectively using traditional regression-based approaches. Fuzzy Set QCA (fsQCA) is particularly suitable for this study because it can handle such **ambiguity** and identify multiple combinations of capabilities (equifinality) that lead to blockchain adoption. Furthermore, fsQCA accommodates asymmetric relationships, where the presence and absence of capabilities can have distinct effects.

Previous studies have predominantly employed SEM and other regression techniques to examine the factors influencing willingness to adopt blockchain. While these methods have provided valuable insights, they inherently limit the findings due to their reliance on linear and additive relationships. For instance, using the SEM technique, Chowdhury et al. (2023) found that resilience plays a significant role in blockchain adoption. However, it does not provide insights into how other factors, such as perceived usefulness (USE) and perceived ease of use (EAS), might interact with resilience or each other to influence blockchain adoption. Regression and SEM focus on the net effect of individual variables, which may overlook the complex, interacting conditions that jointly influence outcomes. This linear approach may fail to capture the nuanced interdependencies present in real-world scenarios, leading to an incomplete understanding of the factors driving willingness to adopt blockchain.

Using fsQCA, we examined six SC capability drivers: information sharing, external collaboration, information integration, communication quality, resilience, and agility. We examined their collective influence on the willingness to adopt blockchain. This fits with the "equifinality" principle, which states that different combinations of these behavioral traits can lead to the same outcome (i.e., intention) (Ragin, 2009). This method differs from traditional methods such as SEM or regression, which might only look at p-values to see if there is statistical significance in missing cases that do not follow the expected pattern (Russo and Confente, 2019).

FsQCA enables examining all combinations of independent variables that can affect a specific outcome (i.e., willingness to adopt blockchain). Unlike conventional statistical approaches like regression and SEM, which typically consider the impact of one independent variable while holding all other independent variables constant, fsQCA analyzes all potential configurations, providing a more comprehensive view of the causal conditions (Fiss, 2011; Gligor, 2020).

4.1. Contrarian case analysis

To explore causal asymmetry, we applied contrarian case analysis. This method allows for examining relationships between two variables within the same dataset, which can be positive, negative, or nonexistent, irrespective of their predominant influence on each other, as Pappas et al. (2016) described. Specifically, we used contrarian case analysis (Russo and Confente, 2019;

Pappas and Woodside, 2021) to identify instances where the connection between SC capability drivers and the willingness to adopt blockchain technology deviates from the expected symmetrical relationships. The findings, presented in Table B (*refer to Supplementary Data Material*), highlight contrarian cases that challenge the primary influence of SC capability drivers on the willingness to adopt blockchain technology.

For instance, Table B shows that while high information sharing significantly influenced willingness to adopt blockchain in some cases (e.g., 25.9% of cases with high information sharing showed high willingness), similar levels of information sharing did not lead to a high willingness to adopt blockchain in other instances (e.g., 17.6% of cases). Similarly, high external collaboration led to a high willingness to adopt blockchain in 39.5% of cases but did not have the same effect in 13.2% of cases. These causal asymmetries highlight the limitations of traditional methods like regression or SEM, which often assume linear, additive relationships. Additionally, as Pappas and Woodside (2021) discussed, the phi coefficient reveals that the association between the SC drivers and the outcome variables is not entirely symmetrical. This discovery supports the use of fsQCA to gain a more nuanced understanding of the asymmetric relationships between SC capability drivers and the readiness to adopt blockchain technology.

4.2 Calibration

The initial preparation stage for fsQCA involved calibrating the scales and transitioning all variables from their original Likert scale format to fuzzy scores. Establishing accurate calibration anchors demands a deep understanding of the substantive and theoretical contexts. When studies incorporate a low number of cases (small-N), researchers often have an intimate knowledge of each case and the overall research study. However, as Greckhamer et al. (2013) note, this case-specific familiarity tends to diminish in larger studies. When a study includes many cases or when the nature and implications of the scale are not conducive to calibration based on in-depth knowledge, researchers may resort to calibration based on the distributional properties of the measures, as suggested by Russo and Confente (2019).

In our approach, we took guidance from Arellano et al. (2021). Our study's measures were calibrated using external data (means and standard distributions) from other research that assessed similar constructs, as shown in Table C *(refer to Supplementary Data Material)*. These external data points were initially considered for calibration.

However, the inconsistencies in the external means and the observation that most of our sample's averages significantly deviated from these means, which could potentially suppress meaningful variation in our responses, led us to discard the idea of using external data for calibration. Instead, aligning with the methodologies proposed by Pappas and Woodside (2021) and Azadegan et al. (2020), we calibrated our 5-point Likert scales by setting the 95th, 50th, and 5th percentiles of each construct as thresholds for full membership, the crossover point, and full non-membership, respectively.

5. Results

The configurations identified in Table 5 provide insights into the willingness of OSCM managers to adopt blockchain technology. These configurations reveal multiple pathways to adoption, showcasing the diversity of causal relationships in real-world SCs. The presence of equifinality—where different combinations of capabilities lead to the same outcome—suggests that firms can achieve blockchain adoption through distinct strategic approaches (Dutta et al., 2020; Queiroz et al., 2020).

A deeper examination of raw coverage, unique coverage, and consistency scores offers further clarity. Raw coverage measures the extent to which a configuration explains blockchain adoption, with higher values indicating more prevalent pathways. Unique coverage represents the proportion of cases explained exclusively by each configuration, highlighting distinct strategic methods. Consistency reflects how reliably a configuration leads to the adoption outcome, with values above 0.83 suggesting robust relationships.

Table 5 Here

5.1. Dynamic collaborators (technology and environment focused)

The Dynamic Collaborators pathway (raw coverage = 0.438, unique coverage = 0.274, consistency = 0.855) is the most prevalent adoption configuration, accounting for nearly 44% of blockchain adoption cases. Firms within this category are generally large enterprises in the retail, logistics, and consumer goods sectors, where external collaboration, information integration, communication quality, SC resilience, and agility serve as key enablers of adoption.

A notable feature of this pathway is the existence of core conditions, which include SC resilience, SC agility, external collaboration, and communication quality, facilitating blockchain adoption for enhancing SC visibility, optimizing collaboration, and improving agility. The peripheral condition of information integration bolsters these initiatives by enabling firms to integrate blockchain into existing IT systems (Li and Fang, 2022; Pandey et al., 2024), although this factor alone is not a primary driver.

Conversely, information sharing is absent, suggesting that firms in this category adopt blockchain chiefly for operational efficiency and resilience, rather than for open data exchange among SC stakeholders (Wang et al., 2021). This indicates that adoption is propelled by selective partnerships rather than extensive transparency, reinforcing the notion that the benefits of blockchain are strategically leveraged rather than uniformly applied.

For instance, Walmart, a global retail leader, integrates blockchain for supplier collaboration, real-time tracking, and communication efficiency, enhancing both transparency and operational performance (Kamath, 2018). This is consistent with research suggesting that firms with robust technological infrastructure and external networks are more likely to adopt blockchain (Clohessy and Acton, 2019). Furthermore, the adoption patterns of blockchain mirror those of emerging digital technologies such as the metaverse (Kumar and Shankar, 2024) and digital twins (Patil et al., 2024), reinforcing the broader trend of digital transformation in SCM.

Finally, the high unique coverage (0.274) underscores that this pathway is highly distinct, meaning that many firms exclusively adopt blockchain through external collaboration and agility-driven strategies. This reflects the principle of equifinality, where different capability configurations can lead to the same adoption outcome.

5.2. Resilient specialists (organization focused)

The Resilient Specialists pathway (raw coverage = 0.270, unique coverage = 0.105, consistency = 0.833) accounts for 27% of blockchain adoption cases and is characterized by firms that prioritize SC resilience while minimizing external collaboration or technological complexity.

Unlike Dynamic Collaborators, firms in this group exhibit a core reliance on SC resilience, while information sharing, external collaboration, information integration, communication quality, and SC agility are entirely absent. This suggests that blockchain adoption is driven by internal risk management rather than external partnerships or IT capabilities.

This configuration is particularly prominent in regulated industries, including pharmaceuticals (Sim et al., 2022), healthcare (Senna et al., 2023), and aerospace (Romano et al., 2024), where regulatory compliance and security concerns necessitate blockchain adoption. For example, Pfizer utilizes blockchain for drug traceability and counterfeit prevention, ensuring compliance with regulatory standards while avoiding external dependencies (Scott et al., 2018).

The absence of information sharing and external collaboration reinforces the view that these firms adopt blockchain primarily as an internal compliance and security tool rather than as an enabler of inter-firm transparency or digital integration (Warkentin and Orgeron, 2020). This aligns with institutional theory, which suggests that regulatory pressures often dictate technology adoption rather than competitive market forces (Malhotra et al., 2022).

The lower unique coverage (0.105) suggests that while some firms exclusively adopt blockchain for resilience, others exhibit hybrid adoption behaviors, combining internal resilience with selective digital investments. This supports the argument that firms in highly regulated sectors balance compliance-driven blockchain adoption with broader technological advancements.

5.3. Proficient collaborators (balanced organization and environment focused)

The Proficient Collaborators pathway (raw coverage = 0.213, unique coverage = 0.046, consistency = 0.856) accounts for 21% of blockchain adoption cases, with firms prioritizing external collaboration, information sharing, and SC agility, while deprioritizing SC resilience, information integration, and communication quality. Unlike Dynamic Collaborators, firms in this category concentrate on enhancing responsiveness and flexibility rather than resilience or deep IT integration. The presence of information sharing as a peripheral condition suggests that while these firms utilize blockchain to improve data exchange, they do not necessarily embed it deeply within their IT infrastructure. Xu et al. (2024) highlight this challenge, noting that a lack of standardized blockchain protocols hinders interoperability across SC IT systems, limiting seamless integration. Furthermore, Mathivathanan et al. (2021) emphasize that low awareness of blockchain technology often compels firms to rely on external service providers rather than invest in in-house IT capabilities.

Conversely, the absence of SC resilience, information integration, and communication quality indicates that firms in this category do not view blockchain as a security or compliance tool but rather as a competitive differentiator for agility and external partnerships. This implies that blockchain is leveraged more for enhancing visibility and responsiveness than for internal operational stability.

This configuration is particularly prevalent in fast-moving industries such as fashion and electronics, where agility and supplier collaboration are critical for market responsiveness. For instance, Zara integrates blockchain to enhance SC transparency and supplier interactions, enabling faster inventory turnover and adaptive decision-making (Kim and Chai, 2017). Similarly, this adoption pattern is highly relevant to government entities, where blockchain is used to streamline public services, enhance contract management, and improve operational agility (Alladi et al., 2019). This suggests that firms and institutions in highly dynamic environments—whether private or public—adopt blockchain primarily to enhance transparency, responsiveness, and collaboration, rather than as a resilience-building tool.

The low unique coverage (0.046) indicates that firms in this category often overlap with other adoption configurations, reinforcing the idea that blockchain adoption through agility and collaboration is not mutually exclusive from technology-driven strategies. This underscores the non-linear nature of adoption, where firms adapt blockchain implementation strategies based on evolving market pressures, competitive dynamics, and technological maturity.

6. Discussion

This study advances the understanding of blockchain adoption in SCs by revealing configurational pathways rather than single-factor influences. The fsQCA results demonstrate that blockchain adoption is not driven by a one-size-fits-all model but instead follows multiple strategic routes, depending on industry context, firm size, and capability configurations.

6.1. Theoretical contributions

First, we advance the literature on factors influencing blockchain adoption by shifting the focus from individual drivers to combinations of capabilities. Previous research has highlighted various determinants, such as infrastructural facilities, government policies, top management support, and organizational readiness (Orji et al., 2020; Clohessy and Acton, 2019), as well as technological challenges, market structures, and inter-organizational trust (Ghode et al., 2020; Janssen et al., 2020; Sciarelli et al., 2022). While these studies treat drivers as isolated factors, our findings demonstrate that firms adopt blockchain through specific configurations of relational, dynamic, and information capabilities. By identifying three distinct pathways—Dynamic Collaborators, Resilient Specialists, and Proficient Collaborators—we reveal that blockchain adoption is not determined by the mere presence or absence of a single capability but by the interplay among capabilities.

Second, we contribute to the literature on the link between DCs and blockchain adoption. Past research has shown that blockchain adoption enhances SC agility and resilience (Chowdhury et al., 2023; Iranmanesh et al., 2023). While these studies focus on what occurs *after* blockchain has been adopted, less is known about what types of relationships exist between these concepts *before* blockchain adoption. In this vein, our study takes a step further by uncovering the causal complexity of these relationships by exploring the impact of SC resilience and agility on firms' willingness to adopt blockchain. Our results show that firms with high SC resilience (Dynamic

Collaborators, Resilient Specialists) and firms with low SC resilience (Proficient Collaborators) both exhibit a willingness to adopt blockchain. Similarly, SC agility can be either absent (Resilient Specialists) or present (Dynamic Collaborators, Proficient Collaborators). These insights challenge the assumption that specific capabilities uniformly drive adoption and instead highlight the importance of examining capability configurations and their interdependencies.

Third, we expand the understanding of relational and information capabilities in blockchain adoption. Previous studies have indicated that firms implement blockchain to improve capabilities such as information sharing, external collaboration, communication quality, and information integration (Ghode et al., 2020; Gligor et al., 2021; Ullah et al., 2022). For instance, Ghode et al. (2020) illustrate that key factors affecting blockchain adaptability include issues related to organizational trust, data transparency, and interoperability. Furthermore, other research suggests that blockchain adoption enhances transparency and accountability (Kshetri 2018), visibility and traceability (Wang et al., 2019), as well as collaboration and trust (Longo et al., 2019).

However, to the best of our knowledge, no other studies have explored capability configurations and their influence on blockchain adoption intent. By contrast to the existing literature, our findings reveal that adoption can occur under multiple pathways where some of these capabilities are absent. For example, Proficient Collaborators exhibit high levels of information sharing and external collaboration but lack SC resilience and communication quality. This demonstrates that blockchain adoption is not contingent on uniformly enhancing these capabilities but depends on the firm's specific capability combinations and adoption context.

Fourth, we make a notable methodological contribution by applying fsQCA to blockchain adoption research (Woodside, 2013; Russo et al., 2016). Unlike traditional regression-based or SEM approaches that assume linearity and symmetry in previous studies (Chittipaka et al., 2023;

Dong et al., 2024; Iranmanesh et al., 2023; Li and Fang, 2022), fsQCA allows us to uncover the causal complexity and asymmetry in adoption decisions. This method highlights the principle of equifinality, showing that firms can achieve similar outcomes (i.e., blockchain adoption) through multiple, equally valid pathways. fsQCA provides richer insights into the nonlinear and context-dependent nature of blockchain adoption by capturing the interplay of capabilities across different adoption scenarios.

Finally, we extend the Technology-Organization-Environment (TOE) framework by integrating organizational capabilities as critical enablers of blockchain adoption (Ganguly, 2024; Malik et al., 2021). While the traditional TOE framework emphasizes technological infrastructure, organizational readiness, and environmental pressures, our findings demonstrate that blockchain adoption is shaped by distinct capability configurations rather than isolated factors. Specifically, Dynamic Collaborators leverage technological enablers (e.g., information integration) and environmental factors (e.g., external collaboration and agility), showcasing high adaptability to external demands and highlighting blockchain as a tool for SC connectivity and efficiency. Resilient Specialists prioritize the organizational aspect, relying primarily on SC resilience to manage disruptions and regulatory compliance while minimizing technological and environmental dependencies. Lastly, Proficient Collaborators balance organizational enablers (e.g., information sharing and agility) with environmental readiness (e.g., external collaboration), indicating that blockchain adoption can be strategically achieved even in the absence of profound technological capabilities integration.

6.2 Practical implications

This study provides actionable insights for SC managers, industry leaders, and policymakers by identifying three distinct pathways—Dynamic Collaborators, Resilient Specialists, and Proficient

Collaborators—through which firms achieve blockchain adoption. These findings emphasize that blockchain adoption is not a one-size-fits-all process but instead depends on specific combinations of technological, organizational, and relational capabilities.

Managers can use the measures provided in Table A to self-assess their firms' levels of information sharing, external collaboration, information integration, communication quality, SC resilience, and agility. Specifically, surveys incorporating these measurement items can be distributed to the firms' SC managers for evaluation. With the collected data, firms can determine which of the three distinct pathways best characterizes their operations. Below, we offer actionable steps for each of the three pathways.

Furthermore, the measurement items in Table A enable managers to assess not only their own scores but also those of current or potential SC members. For example, if a firm is seeking a new supplier willing to adopt blockchain, it can send a survey to the potential supplier to determine whether they should be classified as Dynamic Collaborators, Resilient Specialists, or Proficient Collaborators. We recommend that managers partner with suppliers that fall within the same classification group, as these suppliers are more likely to follow a similar blockchain adoption path. Since successful blockchain implementation requires active participation from suppliers, partnering with those inclined to adopt the technology similarly can streamline the process and reduce potential obstacles.

First, for firms classified as Dynamic Collaborators, blockchain adoption is driven by external collaboration, information integration, communication quality, SC resilience, and SC agility, with information sharing absent from this pathway. These firms leverage external networks and technological integration to enhance transparency, adaptability, and supplier coordination while focusing on collaborative and technological efficiencies rather than extensive internal data-sharing mechanisms. For firms in dynamic industries, such as retail and logistics, blockchain serves as a tool to enhance supplier partnerships and improve responsiveness to disruptions. Managers in such organizations should prioritize investments in technological infrastructure to enable seamless data integration and strengthen external collaboration platforms for real-time communication and partnership alignment. For example, Walmart vividly exemplifies this approach by utilizing blockchain to enhance supplier transparency and improve agility in its operations (Kamath, 2018).

Importantly, managers should note that contrary to prior studies (e.g., Li et al., 2023; Ruangkanjanases et al., 2022), information sharing is not always a prerequisite for blockchain adoption. Previous research has argued that information sharing leads to blockchain adoption when considering technology-related antecedents (Ruangkanjanases et al., 2022) and sustainability goals (Li et al., 2023). However, our findings reveal that firms can successfully adopt blockchain without prioritizing information sharing, as long as they leverage external collaboration, information integration, communication quality, SC resilience, and SC agility. This insight is particularly relevant for firms seeking to implement blockchain while adhering to lean principles (Ahmad et al., 2023). Managers should assess whether redirecting resources toward external collaboration, information integration, and agility can yield similar adoption outcomes with fewer resource commitments.

Second, for firms categorized as Resilient Specialists, blockchain adoption is primarily driven by SC resilience, with external collaboration, technological integration, and SC agility absent. Unlike Dynamic Collaborators, information sharing is neither a driver nor a barrier in this pathway, indicating that these firms do not rely on external data exchange for blockchain adoption. Instead, these firms view blockchain as a risk management tool to strengthen SC resilience, improve traceability, and ensure operational continuity, particularly in regulated or disruption-prone industries. For example, pharmaceutical companies like Pfizer utilize blockchain to enhance product authenticity, comply with regulations, and maintain SC stability, thereby bypassing the need for external collaboration and advanced IT infrastructure investments (Scott et al., 2018).

Managers in regulated industries should recognize that blockchain can be leveraged for resilience-building without requiring extensive external partnerships or deep technological integration. While previous studies suggest that external collaboration, technological integration, and SC agility are primary enablers of blockchain adoption (Foster, 2023; Iranmanesh et al., 2023; Ruangkanjanases et al., 2022), our findings offer an alternative perspective, showing that firms can achieve similar adoption outcomes by prioritizing SC resilience alone. Therefore, firms should assess their existing capabilities and determine the optimal path to blockchain adoption, considering their industry's regulatory landscape and associated risk exposure.

Third, firms identified as Proficient Collaborators adopt blockchain through external collaboration, information sharing, and SC agility, while SC resilience, information integration, and communication quality are absent. These firms rely on strong external partnerships and real-time information sharing to facilitate blockchain adoption without requiring a deep integration into their IT infrastructure. This suggests that blockchain serves as a collaboration and agility tool rather than a security or compliance mechanism. A key challenge for firms in this category is technological fragmentation (Mathivathanan et al., 2021; Xu et al., 2024). Managers should acknowledge these constraints and focus on collaborative blockchain adoption models, ensuring that external partnerships and agility offset limited IT integration.

Beyond these pathways, this study presents a capability assessment framework that enables managers to evaluate their firm's readiness for blockchain adoption. Firms characterized by strong external collaboration and agility align with the Dynamic Collaborator pathway, while those driven by resilience in regulated industries fit the Resilient Specialist pathway. Firms that possess collaborative and agile capabilities but have limited IT infrastructure align with the Proficient Collaborator pathway. This assessment framework serves as a practical tool for managers to identify capability gaps and develop targeted strategies for blockchain adoption.

From a broader perspective, this study also highlights the essential role of policymakers and industry leaders in advancing blockchain adoption. Policymakers should offer regulatory clarity to diminish uncertainty, support industry consortia to foster collaboration, and invest in blockchain-enabled infrastructure to lower entry barriers for firms with limited capabilities. Moreover, educational initiatives and training programs can enhance managerial expertise, ensuring that firms are well-equipped to integrate blockchain effectively into their operations.

6.3. Limitations and future research

While this study offers significant contributions, it is not without limitations, which presents opportunities for future research. First, our study focused on a set of relational, dynamic, and information capabilities influencing firms' willingness to adopt blockchain within the TOE framework. Although this approach provides unique insights into the drivers of blockchain adoption, it does not encompass the full range of capabilities that may be relevant. Future research could incorporate additional capabilities, such as SC flexibility, innovation, ambidexterity, adaptability, or strategic alignment, to build a more comprehensive understanding of blockchain adoption. Studies such as those by Rojo et al. (2016), Gligor (2014), Ali et al. (2024), and Feizabadi et al. (2021) offer potential measures for these constructs, facilitating the testing of these frameworks for future research. Furthermore, it would be valuable to examine the stages of blockchain adoption (e.g., initiation, pilot implementation, full-scale integration), as the role of capabilities may evolve across these stages.

Second, while our study included firms from multiple industries, enhancing the generalizability of our findings, it does not provide industry-specific insights. The drivers of blockchain adoption may differ depending on industry-specific factors, such as regulatory requirements, technological maturity, and SC complexity. Future research could conduct industry-specific investigations to uncover unique adoption drivers within transportation, manufacturing, retail, pharmaceuticals, and food SCs. For example, blockchain's role in traceability may be more critical in pharmaceuticals and food industries, whereas operational efficiency and transparency may dominate in manufacturing and retail contexts. Comparative studies across industries would also help identify both shared and unique factors influencing blockchain adoption.

Third, although our use of fsQCA allowed us to explore the causal complexity and asymmetry of blockchain adoption pathways, additional methodologies could further enhance these insights. Specifically, qualitative interviews with managers and technology adopters could help uncover additional latent capabilities or contextual factors that influence blockchain adoption decisions. These interviews would provide deeper, firm-specific insights into the motivations and challenges associated with blockchain implementation. Moreover, large-scale surveys could complement fsQCA by statistically validating the generalizability of the identified capability configurations across broader contexts. A mixed-methods approach combining fsQCA, interviews, and surveys could provide richer and more robust insights into the factors driving blockchain adoption. To illustrate a potential mixed-methods approach, Study 1 could involve interviewing SC managers to explore the motivations and challenges associated with blockchain implementation, leading to the development of a model that depicts the relationships among these constructs. In Study 2, a survey with a larger sample could be conducted to test the generalizability of the proposed model using regression-based techniques such as Partial Least Squares-Structural Equation Modeling (PLS-SEM). Finally, scholars could apply fsQCA to the Study 2 data to identify any exceptions to the relationships supported by the PLS-SEM results.

Finally, while our study focuses on how the presence and/or absence of capabilities influences firms' willingness to adopt blockchain, similar approaches could be extended to examine other emerging technologies. Future research could explore how these relational, dynamic, and information capabilities—or additional capabilities—affect the adoption of technologies such as artificial intelligence (AI), machine learning (ML), Internet of Things (IoT), 3D printing, robotics, or digital twins. Investigating these technologies would allow researchers to compare adoption pathways across different technological contexts and identify whether similar capability configurations influence adoption across various innovations.

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