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Pre- to post-adoption of blockchain technology in supply chain management: Influencing factors and the role of firm size

Khuram Shahzad [a], Qingyu Zhang [b,*], Muhammad Ashfaq [c], Abaid Ullah Zafar [d], Bilal Ahmad [e]

[a] School of Information Management, Institute of Big Data & Digital Economy, Hubei University of Economics, Wuhan, China
[b] Research Institute of Business Analytics and Supply Chain Management, College of Management, Shenzhen University, China
[c] The Business School, RMIT University, Ho Chi Minh City, Vietnam
[d] College of Business and Public Management, Wenzhou-Kean University, Wenzhou, China
[e] College of Management, Shenzhen University, China

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ABSTRACT

Blockchain technology (BT) provides secure, fast, and confidential distributed systems that can solve many complex issues in supply chain management (SCM). Drawing on the technology, organization, and environment framework, institutional theory, and information system success model, this study proposes a pre- to post-adoption framework for BT in SCM. Data were collected online from 272 upper-level management of Chinese supply chain organizations. The results reveal that pre-adoption factors, including traceability, transparency, organizational readiness, coercive pressure, and normative pressure, positively influence BT adoption, whereas security concerns negatively affect it. The findings further indicate the positive impact of actual use on infusion and performance, and information technology alignment moderates these associations in the post-adoption stage. Interestingly, the moderating results of firm size demonstrate a significant difference in security concerns and organizational readiness, where large organizations have higher readiness and lower security concerns than smaller firms.

1. Introduction

The emergence of innovative technologies has significantly enhanced the efficiency and effectiveness of all businesses, including the supply chain (Shahzad et al., 2022b). However, the survival of organizations in this competitive environment depends on the timely adaptation of these innovative technologies (Shahzad et al., 2023a). These technologies offer several benefits. For example, business services can expand to several geographical locations, enhance real-time information flow, enrich supply chain collaboration, and so on (Kamble et al., 2019; Zhang and Cao, 2018). Supply chain professionals require reliable, accurate, real-time, and quick information to convey from customers to suppliers (i.e., quotation requests, purchase orders, and quality complaints) as well as from suppliers to customers (i.e., order confirmation, inventory report, and dispatch details). Modern technologies can execute these tasks efficiently and effectively for both customers and suppliers. Among modern technologies, blockchain technology (BT) has emerged as a vital game changer in supply chain management (SCM) because of its unique capabilities and benefits such as immutability, traceability, and transparency (Guan et al., 2023; Srhir et al., 2023).

BT is a decentralized data-management technology designed to develop and maintain distributed ledgers (Shang et al., 2023). BT has significant advantages over existing technologies, including data encryption, decentralized consensus, record validation, autonomous contract enforcement, lower cost of adding new participants, and higher visibility (Babich and Hilary, 2020). The implementation of BT in different areas, including SC, makes it a disruptive technology in the Industry 4.0 era (Choi et al., 2022). BT empowers data integrity and decentralized consensus among players without central coordination, as each distributed player can validate, consent to, and reject deals (Lumineau et al., 2021). Researchers have identified external uncertainties and legally unprotected ability issues in China (Wang et al., 2015). BT can alleviate such problems by reducing information asymmetry, enhancing information transparency, and providing digital ownership verification of goods (Tan and Saraniemi, 2023). BT's traceability, automation, resilience, and aggregation properties (Babich and Hilary, 2020) can enable SC professionals, suppliers, and customers to address product quality and visibility issues.

* Corresponding author at: Research Institute of Business Analytics and SCM, College of Management, Shenzhen University, China.
E-mail addresses: khuram7223@yahoo.com (K. Shahzad), q.yu.zhang@gmail.com (Q. Zhang).

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China embraces potential innovative technologies such as BT immediately to satisfy emerging needs and demands. BT was a major innovation that received government investment from over 40 % of Chinese startups in 2017 (Kshetri and Loukoianova, 2019; Shahzad et al., 2022a). By the first-half of 2022, BT investments in China reached approximately 2.5 billion Yuan (Daniel, 2023), which shows that Chinese organizations have a great interest in BT implementation. However, BT-enabled SCM studies on adoption and actual use are still in their infancy (Chod et al., 2020). There are three primary research gaps to be addressed. First, scholars have highlighted various aspects of BT adoption, such as conceptualization (Saberi et al., 2019), pros and cons (Babich and Hilary, 2020), and driving factors (e.g., interoperability, technological volatility, lack of technological knowledge, and regulatory uncertainty) (Clohessy and Acton, 2019; Hartley et al., 2021; Kamble et al., 2020). Nevertheless, many factors underlying the core attributes of BT (e.g., traceability and transparency) and the determinants of environmental legitimacy (e.g., coercion and normative pressure) remain underexplored. Therefore, research is needed to gain a better understanding of these factors, which will assist in identifying stakeholders' motivations and decisions in the implementation of BT in SCM.

Second, BT research in SCM primarily focused on the initial adoption stage rather than the post-adoption stage. BT's effective use will determine whether it can provide an organization with a competitive advantage. Therefore, BT's infusion would help us understand BT-enabled SCM's impact on organizational performance. The recent reviews by Bai and Sarkis (2022) and Zhu et al. (2022) indicated that pre-adoption research has been conducted on BT-enabled SCM, while post-adoption research is needed. Similarly, Babich and Hilary (2020) stated that the initial understanding is relatively clear, but how well BT can be used post-adoption is rather vague. Consequently, a more comprehensive and holistic approach is needed to investigate the post-adoption stage to better understand the role of BT-enabled SCM in organizations.

Third, BT has vast potential as a disruptive technology, especially for large international firms. For instance, using BT, Walmart monitors and traces pork supply in China and records the data of the whole process of a single piece of pork from the slaughterhouse to end-users, including the date and specific period (Kamath, 2018). A famous Chinese e-commerce platform, JD.com, uses BT to trace and record the imports of beef from overseas suppliers (Wu et al., 2021). Both companies reported that using BT enhanced their sales volume (Thomasson, 2019). There are many such reported success stories of BT implementation by large companies. However, it is unclear whether BT can be used in a manner that makes it pertinent to small companies in developing countries because of resource constraints. Are there any differences between large and small companies in their adoption and implementation of BT in SCM?

To fill these research gaps, we employed the technology, organization, and environment (TOE) framework to investigate imperative factors in the pre-adoption phase (Dehghani et al., 2022; Guan et al., 2023). The TOE framework is used because it is flexible and allows the incorporation of different dimensions and theories, as well as contextual determinants of behavior in each dimension (Ahmadi et al., 2017). Following Venkatesh and Bala (2012), contextual and institutional theory factors were investigated based on their prominence in previous BT studies. Although previous studies have identified several key factors, we investigated a few consistently identified critical factors, including legitimacy pressure, organizational readiness, traceability, and transparency (Ar et al., 2020; Xu et al., 2021).

This study not only investigated the underexplored factors that may shape pre-adoption but also uncovered how pre-adoption leads to post-adoption of BT. The post-adoption stage is mainly underpinned by the information system success (ISS) model, which highlights the role of actual use and performance (DeLone and McLean, 2003). Recent studies have highlighted that the performance of organizations (e.g., handling nonstandard orders and improving customer service) should be measured after adopting BT to gauge its impact on SCM (Orji et al., 2020; Wamba et al., 2020). Scholars posit that when an organization takes the initiative to use new technology (e.g., BT), it is difficult to obtain optimal performance without its infusion (Premkumar et al., 1994). According to Sundaram et al. (2007), the "productivity paradox" results from the inefficient use of installed IT systems, indicating that technology infusion is crucial to improve organizational productivity. Furthermore, researchers have established that an organization can benefit by aligning the information technology (IT) system with business objectives, as IT alignment is crucial for enhancing related investments (Hung, 2006; Preston and Karahanna, 2009). Thus, it is important to understand how IT alignment can enhance the associations between actual use, infusion, and performance in BT-enabled SCM.

Researchers have also confirmed that firm size substantially influences BT adoption in SCM, in which large firms tend to adopt BT-enabled SCM more than smaller firms (Clohessy and Acton, 2019). In light of this, we examined the moderating role of firm size to investigate whether large and small firms have different tendencies to adopt and use BT in SCM. Consequently, we address the following key research questions (RQs) arising from the gap in existing knowledge: (1) How do technological, organizational, and environmental factors influence an organization's intention to adopt and use blockchain technologies in the supply chain? (2) How does the actual use of BT in the post-adoption stage enhance its infusion and performance, and how does IT alignment moderate this association? (3) What are the differences for large and small organizations in adopting and using BT in SCM?

By answering the above RQs, this study contributes to the literature on BT-enabled SCM in the following ways. First, it extends the scope of the literature by focusing on the post-adoption phase instead of only assessing initial adoption, as previously explored. Second, we investigate the unexplored BT adoption factors by incorporating the core features of BT (e.g., traceability) and legitimacy elements (e.g., normative pressure). Third, we investigated the moderating role of IT alignment on the associations between (a) actual use and infusion, (b) actual use and performance, and (c) infusion and performance. Fourth, this study examines the moderating role of firm size to confirm whether large and small firms' intentions and use of BT vary in our pre-post model. Finally, the results of this study will facilitate planning and policy development to support BT-enabled SCM in China and other economies facing similar challenges.

2. Literature review

BT is " a fully distributed system for cryptographically capturing and storing a consistent, immutable, linear event log of transactions between networked actors" (Risius and Spohrer, 2017, p. 386). BT is currently used to establish and maintain distributed ledgers, which are considered more secure and immutable than conventional ledgers, such as hash graphs (Babich and Hilary, 2020). BT has been applied in various domains, such as the circular economy (Böhmecke-Schwafert et al., 2022), food delivery (Shahzad et al., 2023b), real state to ensure fraud prevention (Saari et al., 2022), and shared manufacturing (Rožman et al., 2021). BT is identified as a game-changer technology for enhancing SC performance, as all transactions can be traceable, secure, immutable, and transparent, elaborating on the time and location of any business activity (Chod et al., 2020). BT facilitates internal and external integration, improving the efficiency and effectiveness of SC transactions (Deng et al., 2022).

The application of BT in SCM is a major concern for both researchers and practitioners. Prior studies rigorously investigated the implementation of BT in SCM. Table 1 summarizes empirical studies on BT adoption in SCM, indicating that most studies have examined the pre-adoption phase (e.g., behavioral intention), and few studies have examined the post-adoption phase (e.g., continued intention and performance). Deng et al. (2022) examined BT implementation in SCM in the Chinese context and found that top management support, relative advantage, complexity, cost savings, and government support positively

Table 1
Empirical studies on BT adoption in supply chain management.

Author	Country	Theoretical lens	Major findings
Queiroz and Wamba (2019)	India and USA	UTAUT	They determined that transparency, facilitating conditions, social influence, and performance expectations have a positive effect on BI. Behavioral expectations are positively influenced by the trust of supply chain stakeholders, facilitating conditions, and behavioral intention.
Kamble et al. (2019)	India	TAM, TRI, TPB	The study found that Perceived usefulness, attitude, and perceived behavioral control positively affect behavioral intention.
Wamba et al. (2020)	India and USA	N/A	The study established that knowledge sharing, and trading partners positively influence blockchain adoption, and adoption, SC transparency, and BT transparency positively influence supply chain performance.
Karamchandani et al. (2020)	India	TAM	The findings indicated that perceived BT benefits positively impact the perceived usefulness of six dimensions, and these dimensions positively impact perceived incremental profitability except for customer relationships.
Wong et al. (2020a)	Malaysia	TOE	The study established that competitive pressure, complexity, cost, and relative affect behavioral intention.
Wong et al. (2020b)	Malaysia	UTAUT	Findings revealed that facilitating conditions, technology readiness, and technology affinity positively influence behavioral intention, and regulatory support moderates the effect of facilitating conditions.
Alazab et al. (2021)	Australia	UTAUT, ISSM, TTF	The finding established that SC employees' willingness to adopt blockchain was positively influenced by the ISSM, TTF, and UTAUT models.
Queiroz et al. (2021)	Brazil	UTAUT	They revealed that facilitating conditions, trust, social influence, and effort expectancy positively affect BT adoption.
Kamble et al. (2021)	India	TOE, TAM	The findings established that competitor pressure, partner readiness, perceived usefulness, and perceived ease of use as the most influencing factors for blockchain adoption.
(Shahzad et al., 2022b)	China	UTAUT2	The study found that facilitating conditions, price value, habit, user self-efficacy, personal innovativeness, and user satisfaction positively impact continued intention.
Nath et al. (2022)	Bangladesh	TOE, DOI	The study established that firms' intention to adopt BT in SCM is affected by collaborative culture, information sharing, absorptive capacity, top management support, perceived trust, compatibility, relative advantage, and trading partners' pressure.
Deng et al. (2022)	China	TOE	The study found that cost savings, complexity, relative advantage, top management support, SC cooperation, and government support positively affect BT adoption.

Note: Technology acceptance model (TAM), technology readiness index (TRI), and the theory of planned behavior (TPB), information system success model, unified theory of acceptance and use of technology (UTAUT), technology, organization, and environment (TOE) framework, Task technology fit (TTF). Diffusion of innovation theory (DOI).

impact BT adoption. Wamba et al. (2020) studied cross-cultural differences between the USA and India. They confirmed that (a) knowledge sharing and trading partners positively influence blockchain adoption and (b) blockchain adoption, SC transparency, and BT transparency positively influence SC performance. More recently, Shahzad et al. (2022b) studied BT implementation from a Chinese perspective and found that personal innovativeness, user self-efficacy, price value, facilitating conditions, habit, and user satisfaction positively influence continuous intention. This study extends beyond the post-adoption stage, particularly by studying the role of infusion, IT alignment, and firm size, which has never been explored in the BT-enabled SCM context.

2.1. Adoption stages

The diffusion of innovative technology is a complex and dynamic process that may change over time, resulting in an organization's impact (Wu and Chuang, 2010). A multi-stage analysis can provide more insight into innovation diffusion issues and solutions. Kwon and Zmud (1987) developed a six-stage ("initiation, adoption, adaptation, acceptance, routinization, and infusion") model to comprehend the implementation of an information system (IS). Rajagopal (2002) adopted this six-stage model to understand the key factors influencing the application of enterprise resource planning systems. Meyer and Goes (1988) utilized five stages ("awareness, evaluation, adoption, implementation, and expansion"), but Swanson and Ramiller (2004) used four stages ("comprehension, adoption, implementation, and assimilation"), Zhu et al. (2006) employed three stages ("initiation, adoption, and routinization"), and Cooper and Zmud (1990) utilized two stages (adoption and infusion) in the technological innovation setting.

However, scholars are mostly interested in examining the diffusion of innovative technology using two main adoption stages (pre- and post-adoption). For instance, Chang and Zhu (2011) studied networking site adoption, Talwar et al. (2020) investigated the application of mobile payment, Lu et al. (2020) examined the application of healthcare IT, and Gupta et al. (2020) studied the adoption of a mobile wallet using a pre-adoption and post-adoption framework. These studies have established that users' perceptions of innovative technologies might differ in the pre- and post-adoption phases. Accordingly, SC professionals' initial perceptions and willingness to adopt BT may not be sufficient to determine adoption behavior. Thus, we investigate the implementation of BT in SCM using pre-adoption and post-adoption phases through the lens of the TOE framework, institutional theory, and ISS model.

Researchers have highlighted that an organization's innovative technology adoption process depends on its initial intention and how well it meets its needs and demands (Grover and Goslar, 1993). In our study, we defined behavioral intention toward BT as the pre-adoption phase, which is influenced by organizational, environmental, and technological factors. As pre-adoption leads to post-adoption, this study captures post-adoption in light of the ISS model. The use of innovative technology has become a success metric, as it is essential for achieving desired results (DeLone and McLean, 2003). Therefore, it is important to adopt, accept, and infuse BT as scholars have established the positive impact of infusion on innovation (Cooper and Zmud, 1990; Rajagopal, 2002). Accordingly, this study captures infusions in the post-adoption stage. Furthermore, DeLone and McLean (2003) argued that the net benefits must be analyzed to evaluate the real impact of new technologies on organizational performance. Consequently, this study extends the scope of the post-adoption stage by considering the impact of actual use and infusion on performance.

3. Research framework and hypotheses development

The proposed pre-post framework is illustrated in Fig. 1. The pre-adoption phase was examined by integrating the TOE framework and institutional theory. Various studies have employed the TOE framework with different variables to examine BT-enabled SCM (Clohessy and Acton, 2019; Kouhizadeh et al., 2021). These studies have established that the elements related to the TOE framework are critical for understanding the adoption behavior of BT in SCM. In addition, studies on organizational innovation adoption increasingly integrate the institutional theory (Liu et al., 2010; Sherer et al., 2016). The authors suggest that operational channels and the environment can influence firms' attitudes toward innovation. Therefore, we included institutional theory factors (coercive, mimetic, and normative pressure) in the TOE framework to provide a holistic understanding of institutional forces.

In addition, BT provides numerous technology-related benefits, such as traceability and transparency. Traceability and transparency are the most appealing features of BT that encourage companies to adopt it (Kamble et al., 2020). BT is considered a very secure technology; however, researchers have reported numerous security breaches (Yadav et al., 2020), which may adversely affect its adoption. Therefore, the current study explores the role of traceability, transparency, and security concerns in technological factors. The implementation of blockchain technology involves investment in various hardware and software and using the existing IS infrastructure (Agi and Jha, 2022). Hence, we investigated the impact of organizational readiness as an organizational factor. Subsequently, the research framework of this study initially provided insight into the impact of technological, environmental, and organizational factors on behavioral intention.

According to DeLone and McLean (2003), net benefits should be considered when evaluating innovative technology because they reflect the real impact of the technology on organizations and individuals. Scholars have stated that BT can improve SC connections and enhance process innovation (Kamble et al., 2019), but limited empirical evidence is available. Hence, this study enhances the investigation of post-adoption in the ISS model. In line with DeLone and McLean (2003), this study included actual use, an important determinant of infusion, and performance impact. Thus, this study explores how the actual use of BT influences infusion and performance. In addition, significant evidence indicates that IT alignment with organizational strategy is crucial (Morton, 1990; Preston and Karahanna, 2009). Therefore, this study also examined the moderating effects of IT alignment between actual use and infusion, actual use and performance impact, and infusion and performance. Numerous scholars believe that large and small firms have different tendencies to adopt and use innovative technology (Clohessy and Acton, 2019). Accordingly, this study analyzes the moderating role of firm size to explore how large and small firms react differently to under-considered influencing factors at the pre- and post-adoption

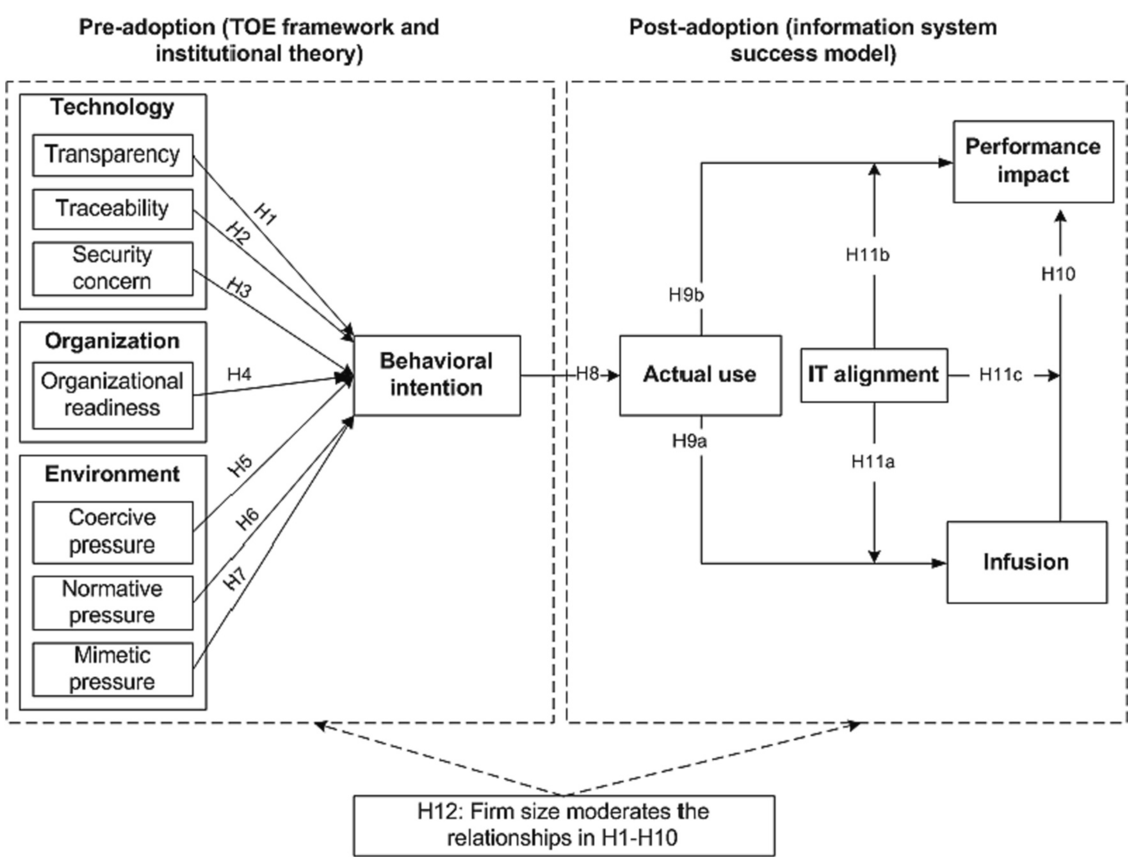

Fig. 1. Research framework.

stages.

3.1. Technological factor

3.1.1. Transparency

The unique features of BT make it an attractive option for organizations seeking to improve their processes efficiently and effectively. Transparency during the SC process refers to each stakeholder's ability to see and access all previous transactions without the involvement of an intermediary. From this perspective, the ability of BT to produce identical copies of data at each node enables real-time data auditing and inspection, ensuring network transparency and making information readily available to all stakeholders (Queiroz and Wamba, 2019). Furthermore, Wamba et al. (2020) determined that SC performance could be substantially enhanced through transparency. Therefore, we argue that BT's transparency enhances SC professionals' intention to use it in SCM.

H1. Transparency positively impacts behavioral intention.

3.1.2. Traceability

Traceability has become an essential requirement for many supply chains, such as the agri-food (Kamble et al., 2020), pharmaceutical (Sánchez-Paternina et al., 2022), and luxury goods industries (Karaosman et al., 2020). Researchers determined that BT offers advanced traceability features, which are pivotal in driving companies to implement BT to increase stakeholders' confidence in SCM (Yadav et al., 2020). In our context, BT-enabled traceability is the ability of an authorized person to trace a specific product and its information such as track history, ingredients, and batch information. Bumblauskas et al. (2020) determined that BT-enabled traceability has become imperative to enhance the relationships between organizations and customers, thus encouraging SC professionals' to implement BT. Therefore, we propose:

H2. Traceability positively impacts behavioral intention.

3.1.3. Security concern

In a digital SC environment, the security and privacy of an organization can be compromised through hacking, unauthorized access to sensitive information, and dissemination of inaccurate data (Kouhizadeh et al., 2021). Organizations can benefit from BT by reducing security concerns and enhancing customer confidence (Orji et al., 2020). Ar et al. (2020) further state that BT stores information in smart contracts, which ensures that communication using BT is highly secure. Although BT is highly secure, scholars have discussed numerous security breaches, indicating that users would have security concerns while using BT (Yadav et al., 2020). Thus, some stakeholders are reluctant to adopt BT in SCM (Saberi et al., 2019). Consequently, we propose the following hypotheses:

H4. Security concerns negatively impact behavioral intention.

3.2. Organizational factors

3.2.1. Organizational readiness

Organizational readiness can be defined as the availability of financial resources and technological capabilities to implement innovative technology (Iacovou et al., 1995). Iacovou et al. (1995) argue that there are two dimensions of organizational readiness: financial resources and IS infrastructure. An organization's financial resources include the availability of funds to install innovative technology, implement subsequent changes, and pay for ongoing expenses (Iacovou et al., 1995). By contrast, IS infrastructure refers to sophisticated telecommunications and databases within departments to implement innovations (Grover, 1993).

Implementing BT in SCM requires new hardware and software (Saberi et al., 2019) and an existing IS infrastructure (Kouhizadeh et al., 2021) for communicating, storing, and collecting data. An organization with a high level of financial resources and compatible IS infrastructure can adopt and continue implementing innovative technologies (e.g., blockchain) that engage in a cooperative environment to increase productivity (Agi and Jha, 2022). Existing studies have established that organizational readiness substantially enhances the adoption of innovative technologies (Agi and Jha, 2022; Iacovou et al., 1995). Similarly, we contemplate that organizations with higher organizational readiness have a higher intention to adopt BT. Therefore, we propose:

H5. Organizational readiness positively impacts behavioral intention.

3.3. Environmental factors

Organizations make rational decisions to enhance performance and consider cultural, social, and legitimacy factors (Sherer et al., 2016). Thus, this study integrates institutional theory to investigate how isomorphic pressures influence BT adoption in SCM. “Institutional theory offers a conceptually rich source to observe the non-linear (as opposed to linear) routes of information technology adoption and assimilation across markets and organizations” (Currie, 2009 P-64). Institutional theory classifies isomorphic pressure into three categories. Coercive pressures are usually exerted by external forces (e.g., industry, government, customers, and suppliers) (Wang et al., 2018). Normative pressure is often exerted through industry standards and norms (Liu et al., 2010). Mimetic pressure comes primarily from an organization's perception of the success of its competitors (DiMaggio and Powell, 1983). We explain how institutional factors influence behavioral intentions in the subsections below.

3.3.1. Coercive pressure

Coercive pressure is defined as the “formal and informal pressures exerted on organizations by other organizations upon which they are dependent and by cultural expectations in the society within which organizations function” (DiMaggio and Powell, 1983, P-150). The extent of coercion is partially affected by the power of the dominant actor, where competition and regulation are the two sources of coercion (Sherer et al., 2016). In the SCM era, BT adoption is driven by external pressure from stakeholders (Farooque et al., 2020). In addition, end users encourage companies to adopt BT to know the origins of the products they buy (e.g., food, gemstones, and minerals) because it is less expensive and more effective than inspection and certification (Hartley et al., 2021). Thus, we propose:

H6. Coercive pressure positively impacts behavioral intention.

3.3.2. Normative pressure

Normative pressure tends to lead to the adoption of innovative technologies in which the norms of the industry and profession are deemed to be effective (DiMaggio and Powell, 1983). Organizations gain innovation knowledge through direct or indirect interactions with adopters (Sherer et al., 2016). However, the implementation of interorganizational information systems is heavily influenced by normative pressure in the SC process (Liu et al., 2010). The standardization of interorganizational SC processes is driven by normative pressures arising from the deployment of information technology by the leading organization within the SC (Hartley et al., 2021). Thus, researchers have highlighted that normative pressure enhances BT adoption in SCM (Hartley et al., 2021). Thus, we propose:

H6. Normative pressure positively impacts behavioral intention.

3.3.3. Mimetic pressure

Mimetic pressure is institutional pressure that encourages an organization to copy the technology or plan of another organization working within the same sector (DiMaggio and Powell, 1983). Haveman (1993) illustrated that mimetic pressure could affect an organization in two ways. First, mimetic pressure occurs when multiple organizations within the same industry use similar tactics. Second, an organization can face mimetic pressure when it struggles to compete with its peers. Organizations affected by such pressures commonly adopt the same strategy to reveal their proficiency to stakeholders or competitors. Consequently, organizations adopt the patterns of other organizations to stay competitive in their fields. This study believes that numerous organizations successfully use BT in their operations, which may assert mimetic pressure on other organizations to adopt BT. Accordingly, the following hypothesis is formulated for this study:

H7. Mimetic pressure positively impacts behavioral intention.

3.4. Behavioral intention

Behavioral intention refers to an individual's desire to use innovative technology (Venkatesh et al., 2003), whereas this study refers to SC professionals' willingness to utilize BT in SCM. Researchers have demonstrated that higher behavioral intention before implementation leads to higher system use after implementation (Sundaram et al., 2007). Most established models and theories in the information system field, such as UTUAT, demonstrated a strong correlation between behavioral intentions and actual use (Venkatesh et al., 2003). Therefore, we propose:

H8. Behavioral intention positively impacts the actual use of BT in SCM.

3.5. Actual use

Actual use can be described as an individual's real usage behaviors of a system (Venkatesh et al., 2003), where positive experiences with the system and its regular use result in infusion (Sundaram et al. (2007). Hence, this study argues that the degree of BT use in SCM determines infusions. Furthermore, the ISS model suggests that the performance of innovative technology (e.g., BT) is the most crucial element to investigate because it represents the actual impact of such technology (DeLone and McLean, 2003). From this perspective, SC professionals can enhance organizational performance using BT (Queiroz and Wamba, 2019). Consequently, this study proposes that BT leads to greater infusion and improved performance.

H9. Actual use positively affects infusion (H9a) and performance (H9b).

3.6. Infusion

Infusion refers to the full potential use of a system (Cooper and Zmud, 1990), which comes after positive usage behavior. We defined infusion as the optimal utilization of BT in SC operations. Sundaram et al. (2007) contended that greater engagement with innovative technology leads to stronger integration, resulting in higher productivity. According to Premkumar et al. (1994), the potential benefits of innovation can be achieved by its infusion. Therefore, an organization that infuses BT into its SC operations can maximize the output-to-input ratio, resulting in a high level of organizational performance.

H10. Infusion positively impacts performance.

3.7. Moderating role of information technology (IT) alignment

IT alignment refers to how IT goals and plans align with business goals (Chan and Reich, 2007). Business functions within an organization are integrated through IT, enabling access to information across the organization (Morton, 1990). Thus, IT alignment is a core concern for business executives and practitioners. Many researchers have concluded that new technology alone cannot provide optimal benefits, but proper integration with existing systems can maximize its benefits (Baker and Singh, 2019). Thus, greater BT alignment with the prior system would improve collaboration, visibility, and transparency among departments, augmenting BT infusion and organizational performance. Subsequently, we built upon this reasoning to argue that IT alignment moderates the associations between actual use, infusion, and performance. Therefore, we propose:

H11. IT alignment positively moderates the relationships between actual use and infusion (H11a), actual use and performance (H11b), and infusion and performance (H11c).

3.8. Moderating role of firm size

Firm size is one of the most significant factors differentiating early and late adopters of innovative technologies. A firm's size can be measured by its number of employees, where a firm with >500 employees is considered large, and a firm with <500 employees is considered small (Knott and Vieregger, 2020). According to Knott and Vieregger (2020), large companies possess sufficient human resources and capital, conduct R&D more effectively, and have higher technological diversity by addressing a broader range of problems and complexity issues. On the other hand, small firms often try to implement the latest technologies to satisfy customer requirements, but their resources limit their ability to embrace innovation (Everett, 1995). From this perspective, researchers have determined that firm size positively influences an organization's ability to adopt and use innovations (Ahmadi et al., 2017), indicating that large organizations tend to have more diverse and complex facilities to adopt and use innovations, while small enterprises have comparatively fewer facilities (Everett, 1995). Clohessy and Acton (2019) recognized that, compared to small-sized organizations, large-sized organizations are more likely to adopt and use BT in SCM due to their advanced research and development efforts to embrace innovations. Thus, firms of different sizes might have a different tendency to adopt and use BT in SCM. Therefore, we propose:

H12. Firm size moderates the relationships proposed in hypotheses H1-H10, such that large firms tend to adopt and use BT more than smaller firms in SCM.

4. Research methodology

4.1. Instruments and pilot test

All constructs were developed from the previously available questionnaire items. Thus, an extensive review of the literature led to the development of 47 items to measure the dependent and independent variables (see Appendix A). Based on innovation diffusion studies, we defined behavioral intention as the initial stage, which refers to an individual's desire to utilize BT (Venkatesh et al., 2003). After intention, there is a stage of formal adoption or actual use, which is defined as the actual usage behavior of SC professionals (Venkatesh et al., 2003). The next stage is infusion, a full-scale deployment in which BT becomes an integral part of the SCM process (Cooper and Zmud, 1990). Consequently, we analyze the application of BT in SCM in a series of steps, beginning with an examination of its feasibility (behavioral intention), formal adoption (actual use), full potential use (infusion), and impact on SC performance. Two professors and SC policymakers examined the draft questionnaire to enhance the content validity of the current study. Modifications to the instrument were made before the initial dissemination of the questionnaire, considering the suggestions made by experts. Respondents were asked to rate each statement on a 7-point Likert scale to indicate their level of agreement or disagreement. Appendix A provides a detailed description of the instrument.

The instrument was first pilot tested. The English questionnaire was translated into Chinese to overcome language barriers. We followed Epstein et al. (2015) prescribed methods (a panel of experts with back-translation) to finalize the Chinese version. To ensure the anonymity of the participants, we provided a complete set of surveys and an explanation of the study's purposes to 40 SC experts with a minimum of 5 years of experience using BT within their respective fields. Respondents were requested to complete the questionnaire and provide feedback. Respondents indicated that the instrument was understandable. Cronbach's alpha was used to ensure reliability of the instrument. All the values were within the threshold limits defined by Hair et al. (2010). Consequently, the questionnaire was distributed to the participants to collect data for the main study.

4.2. Data collection

The survey was designed to target the upper-level management (CEOs, presidents, directors, and managers) of different companies in China. We included respondents with a minimum of ten-year experience in the field of concern and at least one year of experience in using BT. To avoid bias in the results of this study, some screening questions were used to ensure that the respondents had experience or knowledge of using BT for SCM. The target population was organizations that used BT in SC operations in China. In China, there are no technology-driven business news databases. Following Pan et al., 2020, Baidu was used to find companies utilizing BT for SC process. The Baidu search engine was chosen because it is the most popular and contains a wide variety of Chinese websites (Pan et al. (2020). Blockchain technology and supply chain were the keywords used in the search. We found numerous firms utilizing BT in SC practices and included organizations that met the standards of Chinese provisional regulation and the "Organization for Economic Cooperation and Development" (OECD). Most companies are located in Beijing, Guangdong, Zhejiang, and Jiangsu. We emailed a survey to 400 companies in March and April 2022. A weekly email was sent in three waves to improve the response rate. We received 294 responses, but 22 were eliminated from the sample due to incomplete or identical responses, resulting in a final sample of 272 companies with a valid response rate of 68 %. The formula ($N > 50 + 8$ m) by Tabachnick et al. (2007) was used to calculate the minimum sample size, where N is the number of respondents and m is the number of constructs. A total of 272 valid responses met the criteria for this study (272 of 146). Table 2 provides a detailed description of the process.

5. Results

Before testing the research hypotheses through structural equation modeling (SEM), the measurement model's validity (discriminant and convergent) and reliability are examined on SmartPLS. However, a multi-group analysis technique was used to test the moderating variable.

5.1. Measurement model

The measurement model was examined for validity (discriminant and convergent) and reliability, so variables and statements that did not meet threshold limits were deleted. The Fornell and Larcker (1981) criterion was applied to all constructs to determine their discriminant validity. However, the correlations between a particular construct with all other constructs should be somewhat lower than the square root of the average variance extracted (AVE) of that particular construct. Thus, Table 4 shows this framework doesn't have concerns about discriminant validity as bold values (square root of AVE) are higher than correlations. It is recommended by Hair et al. (2010) that a satisfactory convergent validity level requires factor loading above 0.7 and AVE above 0.5 for each item of the construct. As illustrated in Table 3 and Appendix A, the factor loading above 0.7 and AVE above 0.5 for each construct item is higher than the threshold limit. Table 4 revealed that the factor loading and the AVE for each item in the research framework are higher than the threshold values recommended by Hair et al. (2010), except ORD-5, which has been deleted. Cronbach's alpha, composite reliability, and AVE were used to test the reliability of the scale. Table 3 demonstrated that both composite reliability and Cronbach's alpha are higher than 0.7, and AVE is higher than 0.5, indicating that composite reliability is not an issue (Hair et al., 2010).

Using SPSS 22, we employed the Harman (1976) experiment to examine the common method bias (CMB) after obtaining acceptable results with the measurement model. Podsakoff et al. (2003) recommend a threshold limit (<0.5) for the first factor's explanation of variance, the results indicating 28.71 % of the variance explained by the first factor. Thus, Harman's testing shows no problem with CMB.

5.2. Structural model

5.2.1. Direct relationships

The structural model results attained from SEM analysis are presented in Table 5. The hypothesis was rejected or accepted based on the cut-off value of $p < 0.05$. The results confirmed the positive impact of traceability ($\beta = 0.209, p = 0.000$), transparency ($\beta = 0.294$, p = 0.000), organizational readiness ($\beta = 0.337$, p = 0.000), coercive pressure ($\beta = 0.170$, p = 0.000), normative pressure ($\beta = 0.156$, $p = 0.007$) on behavioral intention. While security concern ($\beta = -0.118$, p = 0.007) has a negative, mimetic pressure has no impact on adopting BT in SCM. Moreover, behavioral intention ($\beta = 0.463$, p = 0.000) positively impacts actual use, whereas actual use ($\beta = 0.574$, p = 0.000) positively impacts infusion. Finally, actual use ($\beta = 0.275$, p = 0.000) and infusion ($\beta = 0.349$, p = 0.000) positively influence the performance with 42.9 % of the variation.

5.2.2. Moderating results of IT alignment

This study examined the moderating Impact of IT alignment to enhance infusion and performance impact. Table 6 indicated that IT alignment is a significant moderator that enhanced the relationship between actual use and infusion ($\beta = 0.124$, $p = 0.034$), between actual use and performance impact ($\beta = 0.189$, $p = 0.001$), and between infusion and performance impact ($\beta = 0.209$, p = 0.000).

Table 2
Respondent's characteristics ($n = 272$).

Category	No (#)	%	Category	No (#)	%
Gender			**Firm size**		
Male	183	67.3	1–100	21	7.7
Female	89	32.7	101–250	55	20.2
Age			251–500	67	24.6
30–40	113	41.5	501–1000	88	32.4
41–50	105	38.6	>1000	41	15.1
>50	54	19.9	**Industry**		
Role			Transport and Logistics	83	30.5
Owners/CEO level	72	26.5	Pharmaceutical	32	11.8
Directors	93	34.2	Manufacturing	75	27.6
Manager	107	39.3	Electronics	68	25
			Others	14	5.1

Table 3
Construct's reliability and validity.

Construct	CA	CR	AVE
Traceability (TCB)	0.925	0.947	0.817
Transparency (TSP)	0.925	0.946	0.815
Security concerns (SC)	0.922	0.938	0.716
Organizational readiness (ORD)	0.866	0.866	0.653
Coercive pressure (CP)	0.926	0.947	0.818
Normative pressure (NP)	0.905	0.932	0.820
Mimetic pressure (MP)	0.881	0.927	0.808
Behavioral intention (BI)	0.914	0.946	0.853
Actual use (AU)	0.893	0.949	0.903
Infusion (INF)	0.926	0.938	0.819
IT alignment (ITA)	0.877	0.924	0.768
Performance (PI)	0.943	0.957	0.816

Table 4
Discriminant validity.

	TSP	TCB	SC	ORD	CP	NP	MP	BI	AU	ITA	INF	PI
TSP	**0.904**											
TCB	0.497	**0.903**										
SC	−0.329	−0.256	**0.846**									
ORD	0.448	0.486	−0.316	**0.808**								
CP	0.426	0.323	−0.171	0.332	**0.904**							
NP	0.453	0.519	−0.261	0.381	0.358	**0.905**						
MP	0.050	−0.048	−0.027	0.022	0.097	0.001	**0.898**					
BI	0.620	0.581	−0.406	0.701	0.485	0.524	0.555	**0.924**				
AU	0.424	0.501	0.111	0.565	0.561	0.117	0.554	0.463	**0.950**			
ITA	0.095	0.097	−0.028	0.236	0.106	0.075	0.124	0.172	0.138	**0.905**		
INF	0.307	0.308	−0.02	0.523	0.328	0.043	0.300	0.298	0.530	0.115	**0.876**	
PI	0.257	0.210	0.051	0.266	0.285	0.063	0.392	0.223	0.472	0.088	0.264	**0.903**

Table 5
Results of direct relationship.

Hypothesis	Path	Beta	SE	t-value	*p*-value
H1	TSP → BI	0.294	0.043	6.636	0.000
H2	TCB → BI	0.209	0.034	4.417	0.000
H3	SC → BI	−0.118	0.044	2.678	0.007
H4	ORD → BI	0.337	0.053	6.280	0.000
H5	CP → BI	0.173	0.049	3.503	0.000
H6	NP → BI	0.156	0.058	2.698	0.007
H7	MP → BI	0.012	0.070	0.169	0.886
H8	BI → AU	0.463	0.056	8.312	0.000
H9a	AU → INF	0.574	0.054	13.419	0.000
H9b	AU → PI	0.275	0.076	3.587	0.000
H10	INF → PI	0.349	0.074	4.741	0.000

Table 6
Moderating results of IT alignment.

Hypothesis	Path	Beta	SE	t-value	p-value
H10a	AU × ITA → INF	0.124	0.060	2.073	0.034
H10b	AU × ITA → PI	0.189	0.055	3.416	0.001
H10c	INF × ITA → PI	0.209	0.034	4.417	0.000

Table 7
Moderating results of firm size.

Path	Full sample	Firm size		The difference in path coefficient (P-value)
		Large	SMEs	
TSP → BI	0.294***	0.135**	0.168***	0.628
TCB → BI	0.209***	0.126**	0.263***	0.236
SC → BI	−0.118***	−0.052	−0.261***	0.033
ORD → BI	0.337***	0.383***	0.147**	0.016
CP → BI	0.170***	0.118**	0.261**	0.571
NP → BI	0.156***	0.139**	0.177**	0.660
MP → BI	0.012	0.048	0.062	0.824
BI → AU	0.463***	0.499***	0.415***	0.444
AU → INF	0.574***	0.60***	0.625***	0.794
AU → PI	0.275***	0.376**	0.205***	0.307
INF → PI	0.349***	0.436***	0.328***	0.490

** $P < 0.05$.
*** $P < 0.01$.

5.2.3. *Moderating results of firm size*

This study hypothesized that the firm size has a moderating impact on all independent and dependent variables. The multi-group analysis's empirical outcomes indicated a significant difference in path coefficient between large and SME firms in security concerns and organizational readiness. Table 7 indicated no significant path difference among all other variables of this study. In this perspective, organizational readiness has a positive impact on large (β = 0.383, p = 0.000) and small firms (β = 0.147, *p* = 0.004) on the behavioral intention with a significant difference in path coefficients (β = 0.236, *p* = 0.016). Moreover, there were significant differences in the path coefficients (β =0.209, *p* = 0.033) between large (β = −0.052, p = 0.257) and small firms (β = −0.261, *p* = 0.023) for the impact of security concern on behavioral intention.

6. Discussion

This study proposes a pre-to post-adoption framework for BT in SCM based on the TOE framework, institutional theory, and ISS model. First, the results reveal that pre-adoption factors, including traceability, transparency, organizational readiness, coercive pressure, and normative pressure, positively influence BT adoption, while security concerns negatively affect BT adoption. However, this study found an insignificant relationship between mimetic pressure and behavioral intention. Second, a positive impact of the pre-adoption factor (behavioral intention) on the post-adoption factor (actual use) was found. Next, the relationships between the post-adoption factors (a) actual use and infusion, (b) actual use and performance, and (c) infusion and performance) were found to be positive. Furthermore, this study found that IT alignment is an important moderator in strengthening the associations between actual use, infusion, and performance. Finally, firm size was a significant moderator of security concerns and organizational readiness.

The results showed that traceability is a significant construct in determining behavioral intention. Traceability is a significant challenge for traditional SC, particularly in geographically disconnected and dispersed areas. Customers often seek high product traceability, which puts pressure on organizations to provide product information. Prior literature suggests that using BT in SCM could resolve the traceability issue (Kamble et al., 2020) and enhance trust (Alazab et al., 2021) and satisfaction (Shahzad et al., 2022b). Recently, Shahzad et al., 2023b also confirmed that BT-enabled traceability significantly enhances consumers' continued intention. Thus, BT-enabled traceability would benefit SC stakeholders in resolving consumer-related issues. Moreover, consistent with prior studies, the results of this study indicate that transparency has a substantial positive influence on behavioral intention (Queiroz and Wamba, 2019). The findings of this study suggest that SC professionals believe that the application of BT in SCM improves transparency in the SC process, which can be particularly valuable in SCM, where transparency and trust are critical.

Security concerns were found to be a significant inhibitor of behavioral intention. Numerous BT security breaches have been reported in previous studies (Yadav et al., 2020), which may adversely affect SC professionals' behavioral intention toward BT adoption. Furthermore, Babich and Hilary (2020) highlighted that data deletion and preservation are complicated on BT networks, resulting in privacy concerns. The complexity of data retention makes it challenging to ensure that data is only retained for a reasonable timeframe. Therefore, data may be deleted or retained longer than necessary, compromising privacy. Next, this study found interesting findings regarding security concerns in the moderation analysis of firm size, which demonstrates that security concerns are not significant in large organizations, indicating that large organizations have greater trust in BT. In contrast, security concern is negatively significant in small firms, which specifies that small firms have security concerns regarding adopting BT in SCM. These findings might suggest that large organizations have their own BT setup, are operated by their employees, or have trust in BT service providers. While small firms may have adopted BT from unreliable service providers, they may trust them less. Accordingly, the security concerns concerning BT adoption in SCM depend on the reputation of the BT service provider.

This study found that organizational readiness positively affects behavioral intentions. A prior study on BT established that a lack of organizational readiness hinders its adoption in SCM (Agi and Jha, 2022). BT adoption is, however, more likely to occur when sufficient financial resources and an appropriate IS infrastructure are available (Kouhizadeh et al., 2021; Saberi et al., 2019). Therefore, organizations should recognize the significance of organizational readiness when implementing BT in SCM. Another interesting finding of this study regarding organizational readiness is the moderating effect of firm size, which indicates that large-scale organizations have higher organizational readiness than small firms. This finding indicates that large firms are more likely to adopt BT than small firms, as they have a more compatible IS infrastructure and higher financial resources. Smaller companies, on the other hand, may lack the resources to invest in BT and the necessary IT infrastructure. Therefore, we can conclude that larger companies are more likely to adopt BT than smaller companies.

This finding indicates that coercive pressure positively impacts behavioral intention. Hartley et al. (2021) stated that consumers, wholesalers, and retailers are demanding product safety and traceability, which can be possible with BT, creating pressure on organizations to implement it in SCM. Thus, organizations recognize the importance of implementing BT, leading to increased behavioral intentions. Additionally, we found that normative pressure positively influences behavioral intention. A similar finding was also reported regarding technology adoption (Liu et al., 2010; Sherer et al., 2016). This finding indicates that BT deployment by leading organizations has created normative pressure for other organizations in this sector. This pressure has encouraged other companies to invest in BT, leading to a general adoption throughout the industry. Therefore, coercive and normative pressures are significant determinants of intention. Finally, the mimetic pressure is insignificant. A possible reason for this finding is that the study participants may be highly technology-oriented, gain advantages as prime users, and become influential in SC organizations. Moreover, researchers have argued that the application of BT in SCM is still in the early phase when fewer organizations could gain mimic pressure (Hartley et al., 2021).

This study also found interesting results related to the post-adoption phase. We found that behavioral intention positively impacts actual use, which, in turn, influences infusion. Researchers determined that individuals are more likely to use the technology if they intend to use it, leading to higher infusion rates (Premkumar et al., 1994; Sundaram et al., 2007). Hence, post-adoption strategies should focus on increasing user intent to boost infusion rates. Such findings specify that BT enables SC professionals to trace and track their goods, enhance transparency, and reduce security concerns, potentially encouraging them to use it. Moreover, BT's potential use (infusion) indicates that SC professionals are delighted by BT, enabling multi-source information access and a more prosperous information environment for better decision-making. This study also found that actual use and infusion positively impacted performance. Respondents believed that the potential use of BT could resolve several SC issues, improve SC connections, and accelerate SC operations. Thus, BT enhanced overall SC performance in terms of efficiency and effectiveness, as every stakeholder can monitor key activities that make them confident and satisfied with their operations. Further, the moderation analysis of firm size found no significant differences in the post-adoption phase, indicating that large and small firms face similar challenges in enhancing SC performance after BT implementation.

Finally, this study found unique findings related to IT alignment, which moderated the relationships between (a) actual use and infusion, (b) actual use and performance, and (c) infusion and performance. These findings indicate that IT alignment is crucial when implementing BT in SCM because it enhances the impact of performance by strengthening the associations between performance and its antecedents. Baker and Singh (2019) stated that an IT system should be developed and implemented based on a process perspective, reducing integration problems and allowing cross-departmental, company, and division functions to run more smoothly. Consequently, organizations must not only develop and implement IT systems but also ensure that they are integrated into the entire SC process to maximize BT's effect on organizational performance.

6.1. Theoretical implications

Building on the TOE framework, institutional theory, and ISS model, we develop an integrated model that provides a wealth of information for practitioners and policymakers to understand BT's pre-post adoption in SCM. Several researchers recently examined the implementation of BT in SCM. Most studies have examined BT adoption based on general adoption theories, including the UTAUT (Venkatesh et al., 2003), TAM (Davis, 1989), and TOE (Tornatzky et al., 1990). However, despite the utilization of the TOE framework to explore factors influencing BT adoption in several studies (Dehghani et al., 2022; Deng et al., 2022; Kamble et al., 2021; Nath et al., 2022; Wong et al., 2020a), some factors have not received thorough investigation. For instance, several qualitative and MCDM studies have highlighted factors such as traceability (Kamble et al., 2020), transparency, security concerns (Ar et al., 2020; Xu et al., 2021), organizational readiness (Clohessy and Acton, 2019), coercive pressure, mimetic pressure, and normative pressure (Hartley et al., 2021; Orji et al., 2020). Nevertheless, there remains limited examination of how these factors directly impact behavioral intention in BT adoption within SCM. Therefore, the first contribution of this study is to investigate pre-adoption factors by integrating the TOE framework with institutional theory. Specifically, this research demonstrates institutional theory's potential for BT adoption in SCM through BT adoption studies. By exploring the interactions between the two theories, this study attempts to gain a better understanding of pre-adoption factors and their potential implications. Thus, the study provides insights into how organizations can better manage the pre-adoption process to ensure successful BT implementation.

Moreover, earlier literature mainly studied the initial adoption of BT in SCM (Babich and Hilary, 2020; Bai and Sarkis, 2022; Zhu et al., 2022); the current study now allows us to understand the pre-to post-adoption behavior. Existing studies have explored the importance of satisfaction (Alazab et al., 2021), continued intention (Shahzad et al., 2022b), and performance (Wamba et al., 2020), whereas the significance of actual use and infusion was not explored, which are imperative to enhance the performance of innovative technology (DeLone and McLean, 2003; Premkumar et al., 1994). To gain a better understanding of BT's impact, it was essential to examine both actual use and infusion, two critical elements that have not been explored in existing studies. Thus, the post-adoption phase of the current study establishes the critical role of actual use and infusion in enhancing performance. Furthermore, IS studies have repeatedly revealed the importance of IT alignment in firm performance (Morton, 1990; Preston and Karahanna, 2009); however, BT-enabled SCM studies have overlooked the significance of IT alignment in enhancing firm performance. This study makes unique contributions in the context of BT-enabled SCM by exploring the moderating role of IT alignment in improving the relationships among post-adoption elements: actual use, infusion, and performance. According to Benbya et al. (2019), our findings also contribute to the literature on the consequences of IT alignment since the interaction positively influences actual use and infusion, actual use and performance, and infusion and performance.

Finally, prior studies indicate that large firms are more likely to adopt BT in SCM than small firms (Clohessy and Acton, 2019; Orji et al., 2020). However, the key determinants that encourage large and small firms to adopt BT in SCM have not yet been explored. We empirically address this gap by examining the moderating role of firm size and find its moderation among two pre-adoption variables: organizational readiness and security concerns. The results demonstrate that large organizations have higher readiness and lower security concerns than smaller firms. Thus, our study enhances the understanding of how large and small organizations perceive organizational readiness and security concerns differently. Furthermore, moderation analysis found no significant difference in post-adoption factors, establishing that both large and small firms experience the same challenges after adoption.

6.2. Practical implications

Blockchain technology has emerged as a revolutionary tool in the realm of supply chain management, offering profound insights for practitioners, especially those involved in supply chain (SC) operations and companies embarking on the BT implementation. This study underscores the significant potential of BT, particularly in terms of technological factors, where its traceability and transparency features can play a pivotal role in enhancing firm performance. To fully leverage these capabilities, SC organizations should proactively furnish comprehensive product information, from raw materials to finished goods, using BT's traceability features. Each product or component can be assigned a unique digital identity on the blockchain, enabling the traceability of its entire journey through the supply chain. This traceability is invaluable in scenarios such as product recalls or quality issues, as it expedites the identification of affected items, reducing recall scope and costs. Moreover, BT facilitates the establishment of an immutable and decentralized ledger of transactions. This ledger grants all stakeholders in a supply chain real-time access to data verification. Such transparency fosters trust among participants and diminishes the likelihood of fraudulent activities or errors occurring in the supply chain. For businesses, this transparency aids in the monitoring of supplier performance and ensuring compliance with regulations and standards.

Furthermore, the study highlights potential reservations among small firms regarding BT, stemming from security concerns. To mitigate these concerns, small firms are advised to source BT services from reputable organizations, while the government is encouraged to enact stringent policies to safeguard against security breaches. In contrast to traditional supply chains, which often rely on centralized databases vulnerable to cyberattacks and data breaches, blockchain employs advanced cryptographic techniques to safeguard data. Each transaction is meticulously verified and encrypted, rendering it exceedingly challenging for malicious actors to tamper with the data. This enhanced security not only preserves sensitive information but also ensures the integrity of the supply chain.

Regarding organizational factors, the study identifies a readiness gap, with larger organizations exhibiting greater organizational readiness compared to their smaller counterparts. In response, the Chinese government is urged to formulate policies that incentivize and subsidize small firms, helping them overcome financial barriers associated with BT implementation. For small firms lacking an IS infrastructure, the adoption of BT from a cloud-based development platform is recommended. Recognizing the significance of environmental factors, government policies should be geared toward facilitating BT implementation. These policies should be vigilantly enforced and monitored to ensure their effective execution. The support of external stakeholders is pivotal, as their involvement and stringent government regulations are instrumental in overcoming reluctance among supply chain organizations to adopt BT.

The study underscores the wide-ranging impact of BT utilization on consumers, industries, and society at large, notably in addressing traceability and transparency issues in supply chain processes. Consequently, organizations should devise policies, encompassing both incentives and penalties, to maximize BT's potential in supply chain operations. Research and development departments should explore the seamless integration of BT throughout the entire supply chain spectrum, while IT systems should harmonize seamlessly with end-to-end supply chain operations to optimize BT's advantages in supply chain management. Consequently, the design and implementation of BT should prioritize a process-oriented approach to minimize integration challenges and maximize benefits.

Policymakers are strongly encouraged to promote information sharing with their SC partners, fostering a collaborative environment that enhances communication and ultimately accelerates BT adoption. BT introduces a novel governance model that disrupts conventional practices, enhancing transparency and traceability, and resolving interpersonal conflicts through smart contracts and digital ownership verification. To effectively incorporate BT into supply chain management, organizations must be adaptable, embracing both decentralization and centralization, fostering open communication, encouraging experimentation, and providing continuous support. As blockchain technology continues to evolve, its integration into supply chain management is poised to become more widespread, reshaping the way we oversee, track, and optimize supply chains.

6.3. Limitations and future research

While this study makes a valuable contribution to the investigation of BT for enhancing SCM, it is important to acknowledge certain limitations. First, this study adopts a cross-sectional approach, which may benefit from a longitudinal study in future research. A longitudinal study allows for a more in-depth examination of the adoption and use of BT in SCM by capturing changes in organizational behavior over an extended period. Second, it's worth noting that this research is based on data collected from China, which is a developing nation. To enhance the generalizability of the findings, future studies should consider applying the research framework in other developing and developed nations to validate the results. Additionally, conducting cross-country analyses (e.g., comparing developed and developing nations) could provide a more comprehensive perspective. Last, despite our efforts to comprehensively explore the pre- and post-adoption stages, it's possible that we may have overlooked some factors that influence the pre-post-adoption framework of BT. Future studies should strive to uncover and incorporate these additional factors to further optimize the benefits of BT in enhancing firm performance.

7. Conclusions

Based on an extensive review of related models and theories, in accordance with prior empirical studies on the application of BT in SCM, this study identified interesting barriers and motivating factors in the diffusion of BT in SCM. Thus, this study developed a research framework by integrating three widely accepted models–the TOE framework, institutional theory, and the ISS model–to provide detailed insights to policymakers and practitioners. This study offers insights into how the TOE framework can be applied to the institutional theory and the ISS model in the IS domain, specifically BT's application in SCM in Chinese SC organizations. Accordingly, data were collected from the upper-level management of 272 Chinese SC firms. The empirical analysis determined the critical role of traceability, transparency, organizational readiness, coercive pressure, normative pressure, and security concerns in the behavioral intention to use BT. The findings also determined the critical role of actual use and IT alignment on infusion and performance. Furthermore, infusion positively influences performance. Moreover, this study confirms the moderating role of firm size on two elements: security concerns and organizational readiness. The findings show that large organizations have a more favorable environment for adopting BT than small firms in terms of low-security concerns and sufficient organizational readiness. Finally, SC firms must integrate IT systems with their end-to-end processes to maximize the advantages of BT in SCM.

CRediT authorship contribution statement

Khuram Shahzad: Conceptualization, Methodology, Writing – original draft. **Qingyu Zhang:** Supervision, Conceptualization, Funding acquisition, Methodology, Writing – original draft, Writing – review & editing. **Muhammad Ashfaq:** Writing – review & editing, Validation. **Abaid Ullah Zafar:** Visualization, Investigation. **Bilal Ahmad:** Writing – review & editing, Software.

Data availability

Data will be made available on request.

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Appendix A. Measurement items

Variables/items	Loading
Traceability (Choe et al., 2009; Yuan et al., 2020)	
TCB1: The traceability option is available in a blockchain-enabled supply chain.	0.901
TCB2: Traceability is an imperative feature in the blockchain-enabled supply chain.	0.934
TCB3: The traceability feature in the blockchain-enabled supply chain provides complete information from manufacturer to end-user.	0.916
TCB4: The traceability feature in the blockchain-enabled supply chain provides complete product information.	0.863
Transparency (Queiroz and Wamba, 2019)	
TSP1: I believe blockchain-enabled supply chain procedures would be transparent	0.899
TSP2: I believe supply chain stakeholders will provide me with deep access to how blockchain-enabled supply chain applications work.	0.896
TSP3: I believe supply chain stakeholders will provide me with in-depth knowledge about the applications of blockchain in the supply chain.	0.918
TSP4: I believe I will have opportunities to provide feedback on blockchain-enabled supply chain applications.	0.899
Security concerns (Kamble et al., 2019; Parasuraman, 2000)	
SC1: In my opinion, blockchain technology is not a safe choice for our firm.	0.818
SC2: I am concerned that others will see the information you send via blockchain technology.	0.847
SC3: When you call a business, you prefer to talk to a person rather than a machine.	0.776
SC4: My firm does not feel comfortable doing business with an organization that can only be reached online.	0.884
SC5: A business transaction that is conducted electronically should be accompanied by a written confirmation.	0.869
SC6: When you automate something, you must pay close attention to ensure that the machine or system does not make errors.	0.879
Organizational readiness (Ahmadi et al., 2017; Grover, 1993)	
ORD1: A wide variety of communication technologies are being implemented across most departments in our organization.	0.844
ORD2: Telecommunication technology is widely available in most groups within our organization.	0.862
ORD3: Our databases are extensively shared between numerous applications instead of having separate databases for each.	0.831
ORD4: Our organization has the financial resources to adopt blockchain technology.	0.741
ORD5: In our organization, funding is available to adopt blockchain technology.	Deleted
ORD6: There is a sufficient budget available for adopting blockchain technology at our organization.	0.755
Coercive pressure (Liu et al., 2010)	
CP1: Most of our customers believe that blockchain technology should be implemented.	0.885
CP2: Our important customers may not retain if we don't implement blockchain technology.	0.894
CP3: In the opinion of our main suppliers, we should implement blockchain technology.	0.914
CP4: The strategic cooperation partners who are crucial to our business strongly desire that we should implement blockchain technology.	0.924
Mimetic Pressure (Liu et al., 2010; Wang et al., 2018)	
MP1: Blockchain has greatly benefited our main competitors.	0.833
MP2: Blockchain has greatly reduced the operational costs of our main competitors.	0.904
MP3: Blockchain has increased the competitiveness of our main competitors.	0.974
Normative pressure (Liu et al., 2010)	
NP1: Currently, our suppliers have widely adopted blockchain technology	0.884
NP2: Currently, our competitors have widely adopted blockchain technology	0.924
NP3: Currently, our customers have widely adopted blockchain technology	0.888
Behavioral intention (Queiroz et al., 2021)	
BI1: I intend to use blockchain technology in the future.	0.922
BI2: In the future, I plan to use blockchain technology.	0.936
BI3: In the future, we plan to use blockchain technology.	0.912
Actual use (Isaac et al., 2019)	
USE1: On average, how frequently do you use blockchain technology? - Certainly not; - Less than once a month; - Once a month; - A few times a month - A few times a week; - About once a day; - Several times a day	0.951
USE2: On average, how much time do you spend per week using blockchain technology? - Certainly not; - Almost never; - <2 h; - 2–4 h - 4–6 h; - 6–8 h; - >8 h	0.950
IT alignment (Preston and Karahanna, 2009)	
ITA1: The IT strategy is congruent with the corporate business strategy in our organization.	0.949
ITA2: Decisions in IT planning are tightly linked to the organization's strategic plan.	0.937

(*continued on next page*)

(*continued*)

Variables/items	Loading
ITA3: Our business strategy and IT strategy are closely aligned.	0.829
Infusion (Sundaram et al., 2007)	
INF1: I am using blockchain technology to its full potential for supporting my work.	0.912
INF2: I am using all capabilities of blockchain technology in the best fashion to help me on the job.	0.888
INF3: I doubt there are any better ways to use blockchain technology to support my work.	0.886
INF4: My use of Blockchain technology on the job has been integrated and incorporated at the highest level.	0.821
Performance impact (DeLone and McLean, 2003; Wamba et al., 2020)	
PI1: Blockchain technology assists SC in handling nonstandard orders.	0.917
PI2: Blockchain technology assists SC in handling special customer specification requirements.	0.858
PI3: Blockchain technology assists SC in handling the rapid introduction of the new product.	0.936
PI4: Blockchain technology assist SC in providing short order-to-delivery cycle time.	0.887
PI5: Blockchain technology assist SC in improving customer care performance.	0.916

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Dr. **Khuram Shahzad** is an assistant professor at School of Information Management, Hubei University of Economics. He earned his Ph.D. in Management Sciences from the Beijing university of post and telecommunication and Post-doctorate from Shenzhen University. His research interest is to determine the role of innovative technologies and user behaviors toward these innovations in marketing and supply chain management. He has published papers in well-reputed journals such as Energy, Journal of Retailing and Consumer Services, and the International Journal of Emerging Markets, and Journal of Hospitality Marketing & Management, among others. He is also the reviewer of many SSCI/SCI Journals.

Dr. **Qingyu Zhang** is a Full Professor of Operations Management and Director of the Research Institute of Business Analytics and Supply Chain Management at Shenzhen University, China. He is a Distinguished Professor of Pearl River Scholar. Prior to this, he was a tenured Professor at Arkansas State University, USA. He earned his PhD in Manufacturing Management and Engineering from the University of Toledo, USA, and M. E., B.E. & B.A. from Tsinghua University, China. He is a certified CFPIM fellow by APICS and MCSE and MCSD by Microsoft. His research interests include supply chain management, sustainable operations, and social responsibility. He has published 130+ journal articles and seven books. His work was featured in journals such as JOM, DS, EJOR, Omega, JBE, JBR, TRE, IJPE, IJPR, IJOPM, SCM, JCP, BSE, JKM, I&M, CHB, COR, CIE, IEEE Transactions, and elsewhere. He is "Elsevier Most Cited Chinese Researcher" and "Top 2% Scientists in the World". He won the Jack Meredith Best Paper Award in the Journal of Operations Management in 2016. He serves on the Editorial Review Boards of JOM and Transportation Research Part E.

Dr. **Muhammad Ashfaq** is currently a researcher at The Business School, RMIT University, Ho Chi Minh City, Vietnam. In 2020, he obtained his Ph.D. in Marketing from Dongbei University of Finance and Economics, China. His research interests include marketing (digital marketing), artificial intelligence (human–computer interaction), consumer behavior, technology adoption, and sustainability. His research mainly appeared in Journal of Retailing and Consumer Services, Business Strategy and the Environment, Telematics and Informatics, International Journal of Emerging Markets, Journal of Cleaner Production, International Journal of Bank Marketing, International Journal of Human-Computer Interaction, Sustainable Production and Consumption, and Industrial Management & Data Systems, among others. He is an active reviewer of many international peer reviewed journals.

Dr. **Abaid Ullah Zafar** is an assistant professor College of Business and Public Management, Wenzhou-Kean University, China. He has a PhD in Enterprise Management from the School of Economics and Management, Dalian University of Technology. He also earned his post-doctorate from the Shenzhen-Audencia Business School, Shenzhen University. His research interests are sustainable consumption, sustainable performance, social commerce, social media marketing, and digital celebrities. His work has been published in the Internet Research, Computers in Human Behavior, Business Strategy and Environment, Journal of Knowledge Management, Journal of Cleaner Production, Sustainable

Production and Consumption, Journal of Retailing and Consumer Services, Asia Pacific Journal of Marketing and Logistics, Industrial Management & Data Systems and Telematics and Informatics, among others. He is also the reviewer of many SSCI/SCI International Journals. He has many highly cited papers (top 1 %) and hot papers (top 0.1 %) during 2020 and 2021.

Dr. **Bilal Ahmad** is a highly motivated academician and researcher with more than six years of experience in academia and the corporate sectors. Currently, he is working as an Assistant Professor at Riphah International University, as well as doing postdoctoral research at Shenzhen University, China. There are several papers he has published in reputable journals in the field of marketing, including Industrial Marketing Management, Journal of Business & Industrial Marketing, Asia Pacific Journal of Marketing & Logistics, and Journal of Strategic Marketing, among others.