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Research Paper

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Abstract

This study adopted an affordance approach to examine how supply chain managers interpret the possible benefits that can be obtained in blockchain enabled supply chain applications. With a focus on governance efficiency improvement, the effects of traceability and transparency affordance on uncertainty reduction were examined from the perspective of transaction cost theory in the supply chain industry. Partial least squares–structural equation modelling was used to analyse the data collected from 364 experienced supply chain managers in China. The results revealed that traceability affordance exerted larger significant effects on environmental and trading-partner uncertainty than transparency affordance, which, in turn, affected the adoption intention. This study contributes to the literature by embedding transaction cost in blockchain affordances. The findings are useful in guiding practitioners to improve blockchain system design to reduce uncertainties in the supply chain environment, leading to a higher rate of blockchain technology adoption.

Keywords: Blockchain technology, Supply chain management, Affordance theory, Transaction cost theory.

1 Introduction

Supply chain management (SCM) is increasingly challenging due to frequent interactions among an ever-growing number of stakeholders, a high level of outsourcing and rapid globalisation (Bode & Wagner, 2015). This complex structure makes the supply chain lengthy and widely dispersed, creating more uncertainty in SCM (Manupati et al., 2020). Blockchain technology is considered to be a potential solution to the challenges of information visibility and transaction traceability in the supply chain industry (Wong, Tan, et al., 2020). Supply chain companies can record transaction information in blockchain enabled applications that are connected to various stakeholders, making the system secure, immutable, and irrevocable (Manupati et al., 2020). Although the future development of blockchain technology seems promising, some firms remain hesitant to adopt it in SCM for various reasons, such as reluctance to change, lack of capability, or high investment cost (Rejeb et al., 2022). Therefore, the factors driving firms to adopt blockchain technology have attracted the attention of scholars and practitioners. For instance, studies have applied the technology acceptance model (TAM) (Li et al., 2021; Yang, 2019), the unified theory of acceptance and use of technology (UTAUT) (Queiroz & Fosso Wamba, 2019), and the fit-viability model (Liang et al., 2021) to study the intention to adopt blockchain technology. However, studies have not considered the contribution of blockchain technology to governance efficiency in supply chain relations. Empirical research on how firms use an institutional economics approach to make blockchain investment decisions is scant (Ahluwalia et al., 2020). Schmidt and Wagner (2019) recommended that future studies adopt a theoretical framework based on organisation economics to explain how blockchain technology contributes to governance efficiency in SCM. Drawing on transaction cost theory, the current study aimed to examine how blockchain technology can improve governance efficiency in SCM (e.g., environmental and trading-partner uncertainty reduction), which, in turn, affects the intention to adopt blockchain technology.

The extant literature has mainly focused on the effects of technological benefits on blockchain adoption intention; it has not considered which capabilities of blockchain technology enable managers to attain their desired goals in a supply chain (Burton-Jones & Volkoff, 2017). According to affordance theory, there are two major stages in the affordance process, namely affordance perception and affordance actualisation (Strong et al., 2014). ‘Affordance perception’ refers to the fact that users’ interpretation of a technology can vary according to the users’ objectives (Leonardi, 2013). ‘Affordance actualisation’ refers to the actions taken by users to achieve concrete outcomes (i.e., desired goals) by taking advantage of the affordances of a technology (Rockmann & Gewald, 2018). As mentioned, a desired goal may be to reduce uncertainty in a supply chain, and this may be achieved by using blockchain technology features. Thus, by integrating the affordance perspective with transaction cost theory, this study proposed two types of blockchain technology affordance, namely transparency and traceability, arguing that these affordances have the potential to affect how managers evaluate environmental uncertainty and trading-partner uncertainty. The proposed research question was as follows. *From the perspective of transaction cost theory, how do blockchain technology affordances, through minimising supply chain uncertainties, motivate supply chain firms to adopt blockchain technology?*

This study responds to calls for research on the technological impacts of blockchain technology on governance efficiency in SCM (e.g., Ahluwalia et al., 2020; Kummer et al., 2020; Schmidt & Wagner, 2019) and contributes to theory and practice in three distinct ways. First, most studies have evaluated the functionality of blockchain technology based on the TAM (Li et al., 2021; Yang, 2019) and UTAUT (Park, 2020; Queiroz & Fosso Wamba, 2019). However, the original scales of the TAM and UTAUT are too abstract (Shih, 2004), overlooking the question of which key capabilities of blockchain technology effectively help managers to attain their desired goals. This study enriches the information systems (IS) literature by investigating how managers interpret blockchain technology and their resulting supply chain evaluations from the affordance perspective. Second, a group of blockchain studies have proposed applying a transaction cost model to SCM in future research, arguing that blockchain technology has the potential to change transaction costs. However, such studies have been limited to qualitative study types such as case study (Schmidt & Wagner, 2019), systematic review (Kummer et al., 2020), conceptual framework development (Ahluwalia et al., 2020), and object-oriented analysis (Chang et al., 2019). An empirical understanding of how blockchain technology improves the governance efficiency of supply chain firms in terms of transaction cost is absent from the literature. To the best of our knowledge, we are the first to empirically examine the effects of two blockchain affordances on supply chain managers’ evaluation of their governance efficiency in terms of minimising uncertainties. Third, our empirical findings provide fresh insights into the design of blockchain systems.

2 Theoretical background

2.1 Blockchain technology in supply chain management

Blockchain is a protocol of transparent, secure, and open distributed ledger technology (DLT) that removes the need for a trusted intermediary (Marikyan et al., 2022). It was first applied as the Bitcoin protocol (Nakamoto, 2008). Blockchain plays a critical role in SCM by creating a platform connecting all stakeholders in a supply chain, such as manufacturers, retailers, distributors, suppliers, and consumers. A blockchain-enabled system allows all of the involved parties to record logistics, track and monitor dynamic supply chain activities in real time, and to transparentise capital flow and information flow (Yuen et al., 2018). Records in a blockchain system are difficult to change, as doing so requires a consensus to be reached by supply chain parties (Akhavan & Philsoophian, 2022). As a result, scholars have expressed the belief that blockchain technology can help to tackle governance issues in supply chains (Schmidt & Wagner, 2019; Wong, Leong, et al., 2020). Although empirical studies on blockchain adoption have examined the effects of similar blockchain features, such as tracking, tracing, transparency, and traceability, on trust and satisfaction (Joo & Han, 2021) and on intention to adopt blockchain in the aviation industry (Li et al., 2021) and maritime shipping (Yang, 2019), they have failed to explain how blockchain technology contributes to governance efficacy. Drawing on affordance theory, we investigated two widely discussed features of blockchain, namely traceability and transparency, to explore how managers perceive the potential of blockchain to address their governance problems (e.g., uncertainties) in a supply chain. In this research context, 'blockchain enabled supply chain applications' refers to a supply chain system that uses blockchain technology tools and infrastructure to support planning and/or managing supply chain activities (Nandi et al., 2020).

2.2 Affordance theory

The term 'affordance' is used to describe how a goal-directed actor can use a given object in a specific environment or to fulfil a specific goal (Gibson, 1977). 'Technological affordance' relates to what a given technology offers for the effective development of actors' needs (Dincelli & Yayla, 2022). Thus, affordance provides a theoretical lens through which to conceptualise and explain IS adoption, thereby helping practitioners to design user-centred technologies (Wang et al., 2018). Given its importance, recent studies have applied the concept of affordance to examine mechanisms driving the business success of new technologies, particularly studies on blockchain affordance and adoption (Du et al., 2019; Kewell et al., 2017; Shin & Bianco, 2020). In this regard, two distinguishing capabilities of blockchain technology, namely transparency and traceability were selected for discussion, for the following reasons in this study. Transaction records and product information are facilitated by a consensus algorithm and shared in secure and immutable ledgers in blockchain systems (Chang et al., 2019). For example, blockchain-based supply chain systems enable stakeholders to participate in real-time sharing of information about inventory and financial flows (Aslam et al., 2021; Kamble et al., 2020). Each transaction can be verified by all of the authorised participants across the supply chain in real time by using the synchronised, shared ledgers of immutable data (Ducrée, 2020). In this context, 'transparency affordance' refers to the extent to which blockchain enables information transparency regarding supply chain activity (Queiroz & Fosso Wamba, 2019; Wong, Leong, et al., 2020). Another type of affordance involves the use of blockchain technologies to allow supply chain firms to trace the provenance of each transaction, thereby providing comprehensive information to decision makers (Shin & Hwang, 2020). 'Traceability affordance' refers to the extent to which blockchain technology offers the potential to trace and verify all of the information about supply chain activities (Joo & Han, 2021).

2.3 Transaction cost theory

Transaction cost theory (TCT) is used to minimise transaction costs by optimising the governance structure of an organisation (Coase, 1937; Williamson, 1981). Williamson (1981) extended TCT by incorporating three key factors – asset specificity, transaction frequency, and uncertainty – that contribute to transaction costs. Asset-specific investments are required when a firm aims to maintain an ongoing relationship with exchange partners and the maintenance of this relationship incurs higher switching costs (Williamson, 1985). The costs of related management and haggling rise when the frequency and volume of transaction activities increase (Williamson, 1985). 'Uncertainty' here refers to unexpected changes in the circumstances surrounding a deal (Grover & Malhotra, 2003). According to Schmidt and Wagner (2019), business uncertainties and opportunism may be reduced and restricted in the blockchain environment, as the characteristics of blockchain technology address these problems, allowing for the improvement of governance efficiency in SCM. Therefore, this study mainly focused on the effects of blockchain technology on supply chain uncertainties from the perspective of the transaction cost model. Specifically, this study examined the two types of uncertainty that drive costs, namely environmental uncertainty and behavioural uncertainty (Grover & Malhotra, 2003; Williamson, 2002).

2.3.1 Environmental uncertainty

In SCM, delivery and product uncertainty are two commonly discussed environmental factors influencing a firm's performance (Gaonkar & Viswanadham, 2007; Tse & Tan, 2012). Delivery uncertainty occurs when raw materials or finished goods are delivered to the incorrect location, perhaps as a result of poor arrangements or planning by partner companies (Desai et al., 2015). When vendor firms outsource a portion of their jobs to third parties, this can cause problems with product quality.

2.3.2 Trading partner uncertainty

Trading partner uncertainty involves behavioural uncertainty and opportunism; both have been widely discussed in the transaction cost literature (Ellram et al., 2008; Grover & Malhotra, 2003; Ketchen & Hult, 2007). 'Behavioural uncertainty' refers to difficulty in monitoring and evaluating the contractual performance of trading partners (Williamson, 1985). 'Opportunism' refers to self-interested behaviour by trading parties (Gulbrandsen et al., 2009), such as information withholding, cheating, or any other form of contract breach (Morgan et al., 2007).

3 Research model and hypothesis development

Figure 1 shows the research model used to determine how blockchain affordances affect supply chain uncertainties, which in turn influence a firm's intention to adopt blockchain enabled supply chain applications.

3.1 Relationship between transparency affordance and environmental uncertainty reduction

Transparency is inextricably linked with information provision (Venkatesh et al., 2016). Increased information transparency in supply chain systems provides managers with more information to control and manage product quality, thereby reducing product uncertainty (Schmidt & Wagner, 2019). In the food supply chain, each product can be monitored in detail by blockchains, for example in terms of its cost, location, and date of production. In this way, businesses are better able to guarantee their food's quality (Bai & Sarkis, 2020). Production, logistics, and sales can also be checked by blockchains, making it easy to identify incorrect locations, processing errors, and timing issues (Baralla et al., 2019). Furthermore, the supply of products is better monitored via blockchain technology, in that it allows for tracking of problems in the delivery of items, such as damage or storage problems (Xu et al., 2020). Based on our argument, we proposed the following hypotheses:

H1: Transparency affordance positively affects delivery uncertainty reduction.

H2: Transparency affordance positively affects product uncertainty reduction.

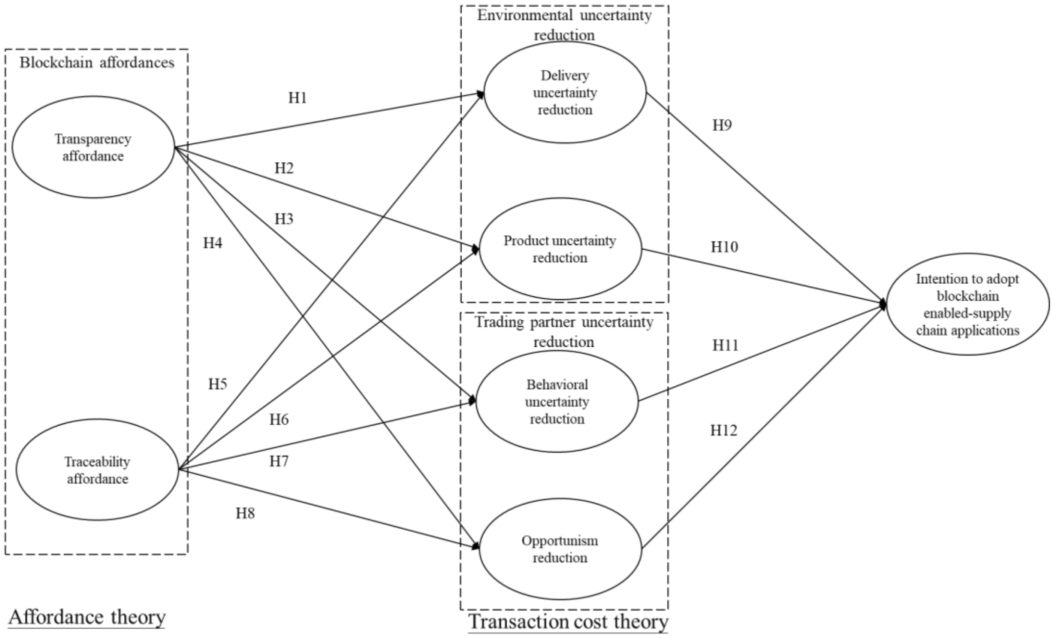

Figure 1. Research model.

3.2 Relationship between transparency affordance and trading partner uncertainty reduction

Contracting parties are motivated to monitor any opportunistic behaviour of their trading partners to protect their own interests (Saberi et al., 2019). Due to information asymmetry, it is difficult for firms to evaluate the performance of their trading partners (Ireland & Webb, 2007). The transparency afforded by blockchain technology may help to eliminate information asymmetry between trading parties, thereby limiting opportunistic behaviours (Shahab & Allam, 2020). Tian (2016) suggested that information is less likely to be distorted in blockchain supply chain systems, as transaction information is shared among and protected by all of the involved parties. As such, any unauthorised revisions, such as subtle breaches of agreements or amending critical information, are easily and immediately detected, deterring the parties from engaging in opportunistic behaviours (Schmidt & Wagner, 2019). Additionally, Saberi et al. (2019) proposed that information is easy to access by all of the stakeholders in a blockchain-enabled system, facilitating the performance evaluation of each party in this transparent environment. This led to the following hypotheses:

H3: Transparency affordance positively affects behavioural uncertainty reduction.

H4: Transparency affordance positively affects opportunism reduction.

3.3 Relationship between traceability affordance and environmental uncertainty reduction

Blockchain is fundamental to solving traceability problems in SCM (Lu & Xu, 2017; Mathivathanan et al., 2021; Wamba & Queiroz, 2020). For example, blockchain is a promising technology for the tracing of products' locations in real time, through loading and transfer, thus providing operators control over air cargo (Gao et al., 2019). It logs all of the steps of delivery, rendering this information is traceable, preventing packages from being lost and reducing fraud claims (Yang, 2019). Ludeiro (2018) studied how blockchains are able to track the locations of products more precisely and decrease the loss and damage of products. Li et al. (2021) proposed that the traceability afforded by blockchains addresses problems regarding interconnection and information authenticity. Moreover, Madhwal and Panfilov (2017) pointed out that counterfeit products cannot be verified through blockchains, which helps to reduce the need for correction, thereby improving the safety of products and reducing the possibility of fraud (D. D. Shin, 2019a). Based on the fact that the traceability of product items reduces both delivery and product uncertainty in SCM, we proposed the following hypotheses:

H5: Traceability affordance positively affects delivery uncertainty reduction.

H6: Traceability affordance positively affects product uncertainty reduction.

3.4 Relationship between traceability affordance and trading partner uncertainty reduction

Blockchain traceability has the potential to prevent fraud between supply chains (R.-Y. Chen, 2018; Loop, 2016). Stranieri et al. (2021) pointed out that product traceability allows all of the partners throughout a supply chain to share the traced product data. In addition, Chen et al. (2021) proposed that the blockchain system allows for the permanent retention of the trajectory of persons and organisations because of the immutability of blockchain information. As such systems can track information concerning both entities and people and the information cannot be deleted, they are very helpful in a strong credit restraint mechanism. Schmidt and Wagner (2019) further pointed out that the cost of information collection, information processing, and relationship management are minimised by blockchain technology, thereby reducing the complexity of transactions, information asymmetry, and contractual incompleteness. Based on the above discussion, we proposed the following hypotheses:

H7: Traceability affordance positively affects behavioural uncertainty reduction.

H8: Traceability affordance positively affects opportunism reduction.

3.5 Relationship between environmental uncertainty reduction and intention to adopt blockchain enabled-supply chain applications

According to perceived risk theory in the discipline of IS, when users perceive a high risk in using a given technology, their intention to adopt the technology is significantly impaired (Thusi & Maduku, 2020). Edrisi and Ganjipour (2022) examined the impact of delivery risk on users' intention to adopt autonomous delivery robot technology, mediated by user attitude. The users held concerns about this new technology's delivery performance, such as the potential for wrong delivery destinations or product damage. The study predicted that users' perception of risk would negatively affect their attitude towards using a given technology, which would negatively affect their intention to use it. The study confirmed that delivery risk had a negative impact on users' attitudes, thereby reducing their intention to use it. Similarly, e-commerce studies have proposed that customers have difficulty assessing the quality of physical products over the Internet, raising the possibility that the products' features may not match their expectations and thereby reducing the likelihood of their shopping online (Kamalul et al., 2018; Masoud, 2013). Based on the above discussions, we proposed the following hypotheses:

H9: Delivery uncertainty reduction positively affects supply chain managers' intention to adopt blockchain enabled supply chain applications.

H10: Product uncertainty reduction positively affects supply chain managers' intention to adopt blockchain enabled supply chain applications.

3.6 Relationship between trading partner uncertainty reduction and intention to adopt blockchain enabled-supply chain applications

It is difficult for a firm to accurately evaluate the performance of its trading partners, resulting in behavioural uncertainty (Morgan et al., 2007). Opportunism arises because of a heavy reliance on trading partners and limited transparency among supply chain entities (Lumineau & Oliveira, 2020). As a result, behavioural uncertainty and opportunism may lead to trust problems and, ultimately, the termination of the business relationship (Gulbrandsen et al., 2009). Blockchain technology alleviates this problem by providing decentralised consensus records, thereby reducing opportunistic behaviours and permitting a more accurate evaluation of contracting parties' performance (Lumineau & Oliveira, 2020). When blockchain technology alleviates the concern of opportunism and partnership performance, supply chain managers are more likely to adopt blockchain technology (Roeck et al., 2020). Therefore, we developed the following hypotheses:

H11. Behavioural uncertainty reduction positively affects supply chain managers' intention to adopt blockchain enabled supply chain applications.

H12. Opportunism reduction positively affects supply chain managers' intention to adopt blockchain enabled supply chain applications.

4 Research methodology

4.1 Sample and data collection

This study targeted supply chain managers in China as the study sample. We selected the setting of China because China is a developer and early adopter of blockchain technology in various industries, including supply chain, energy, medicine, and finance (Hsu & Green, 2021). With the government's support, blockchain application usage has increased across the country (Hsu & Green, 2021). For instance, in the first quarter of 2017, over 40% of Chinese startup companies had received governmental seed funding for blockchain-related technologies (Mark, 2018). Furthermore, China was ranked as the top adopter of blockchain technology globally, with 58,990 relevant patents filed, demonstrating the Chinese government's embracing of blockchain technology as part of its technological landscape through various initiatives (World Intellectual Property Organization, 2020). Many Chinese companies have applied blockchain technology in their SCM, including Walmart China (Zmudzinski, 2019) and JD Digit (Wood, 2019). We thus believed that Chinese supply chain managers' perceptions of blockchain technology adoption would be meaningful, providing both theoretical and practical implications. In June 2022, we hired SoJump, a leading survey company in China with more than 43 million members in various Chinese cities (Zheng et al., 2020; Zhou et al., 2013), to collect the data. Online survey companies generally have national databases, providing high levels of sample diversity and cross-validation ability, which both serve to increase the generalisability of study results (Chi, 2018). Many studies have used this large-scale online consumer survey platform to collect management data in China. These studies' target samples have included Chinese expatriate managers (Zhang et al., 2022), Chinese frontline employees (Zhang, 2019), supply chain managers in China (Liu et al., 2022; Spillan et al., 2018), and HR managers (Suseno et al., 2022). Therefore, this national database was used to ensure the representativeness of our study sample. The study initially recruited 407 survey respondents. At the beginning of the survey, the definitions of 'blockchain' and 'blockchain technology enabled supply chain system' were presented to the participants (Marikyan et al., 2022; Nandi et al., 2020). Two screening questions were included to validate the appropriateness of each respondent. Respondents who had less than five years of professional experience in the supply chain industry and those who were not involved in new IT technology decision-making were excluded from the study. To ensure data validity, two additional procedures were used to screen out invalid responses. First, following common data cleaning practice (Zhou et al., 2013), we removed respondents who had taken less than 10 minutes to complete the survey according to the online system. Second, respondents were removed if they answered the attention questions incorrectly. Ultimately, we obtained 364 valid responses. All of the respondents were senior executives of Chinese supply chain companies, and 45.1% of them had at least five years of professional experience in the supply chain field. All of the respondents had at least a bachelor's degree (64.3%). More than 31.3% of the respondents' companies had annual revenues between RMB50 million and 100 million, and more than 34.1% had been using blockchain technologies for at least three years. Moreover, the respondents were distributed across a wide range of industries; 36.5% of the respondents hailed from the manufacturing industry, specialising in high technology. Overall, the sample of respondents was deemed appropriate for our research objectives.

4.2 Instruments of measurement

The items in the questionnaire were adapted from prior studies (see Appendix A), and the responses were given on a 7-point Likert scale, ranging from 'strongly disagree' to 'strongly agree'. Four IS professors and two practitioners reviewed the survey's content validity. We modified the wording of the measurement items according to their comments to fit the research context and translated the survey into Chinese using the back-translation approach (Bhalla & Lin, 1987).

5 Data analysis and results

Partial least squares–structural equation modelling (PLS-SEM) was used to conduct the data analysis, using SmartPLS 4.0.8.3 (Ringle et al., 2015). PLS-SEM is considered to be an advantageous technique for exploratory research, given its appropriateness for research with a large number of constructs and its ability to identify key predictors even in relatively small samples (e.g., fewer than 500 responses) (Hair et al., 2017).

5.1 Results of measurement model

Item loadings and composite reliability (CR) were used to assess the reliability of the latent constructs (Hair et al., 2017). During the purification process, one item (DUR3) was excluded due to item-loading concerns to achieve a valid and dependable instrument. The loading of the remaining items exceeded 0.70, ranging from 0.71 to 0.87. All of the CR values exceeded 0.70, ranging from 0.80 to 0.91, thus demonstrating a high level of internal consistency (Nunnally & Bernstein, 1994). Average variance extracted (AVE) was used to assess the convergent validity of the model. All of the AVE values were greater than the 0.5 threshold, satisfying the AVE criterion (Hair et al., 2017). We used heterotrait-monotrait (HTMT) ratios to evaluate discriminant validity. All of the constructs' HTMT ratios were smaller than the 0.85 threshold (Henseler et al., 2015), confirming the discriminant validity of the model (Table 1).

Constructs	BUR	INT	OR	DUR	PUR	TRAC	TRAN
BUR							
INT	0.55						
OR	0.48	0.44					
DUR	0.57	0.57	0.36				
PUR	0.83	0.67	0.45	0.62			
TRAC	0.67	0.67	0.40	0.60	0.67		
TRAN	0.60	0.70	0.33	0.45	0.68	0.77	

Table 1. Discriminant validity: HTMT ratio.

5.2 Structural model

As presented in Figure 2, the model explained 29% of the variance in product uncertainty reduction, which was significantly determined by transparency affordance ($\beta = 0.30$, $p < 0.001$) and traceability affordance ($\beta = 0.29$, $p < 0.001$), supporting H2 and H6. Furthermore, the model explained 19% of the variance in delivery uncertainty reduction, which was significantly determined by traceability affordance ($\beta = 0.37$, $p < 0.001$), supporting H5. Moreover, the model explained 30% of the variance in behavioural uncertainty reduction, which was significantly determined by transparency affordance ($\beta = 0.23$, $p < 0.001$) and traceability affordance ($\beta = 0.38$, $p < 0.001$), supporting H3 and H7. Furthermore, the model explained 12% of the variance in opportunism reduction, which was significantly determined by traceability affordance ($\beta = 0.28$, $p < 0.001$), supporting H8. Lastly, the model explained 35% of the variance in intention to adopt blockchain enabled supply chain applications, which was significantly determined by delivery uncertainty reduction ($\beta = 0.20$, $p < 0.001$), product uncertainty reduction ($\beta = 0.28$, $p < 0.001$), and opportunism reduction ($\beta = 0.20$, $p < 0.001$), thereby supporting H9, H10 and H12. However, the effects of transparency affordance on delivery uncertainty reduction ($\beta = 0.09$, $p > 0.05$) and opportunism reduction ($\beta = 0.11$, $p > 0.05$) were non-significant, thus rejecting H1 and H4. The relationship between behavioural uncertainty reduction and intention to adopt blockchain enabled supply chain applications ($\beta = 0.11$, $p > 0.05$) was also non-significant, thus rejecting H11.

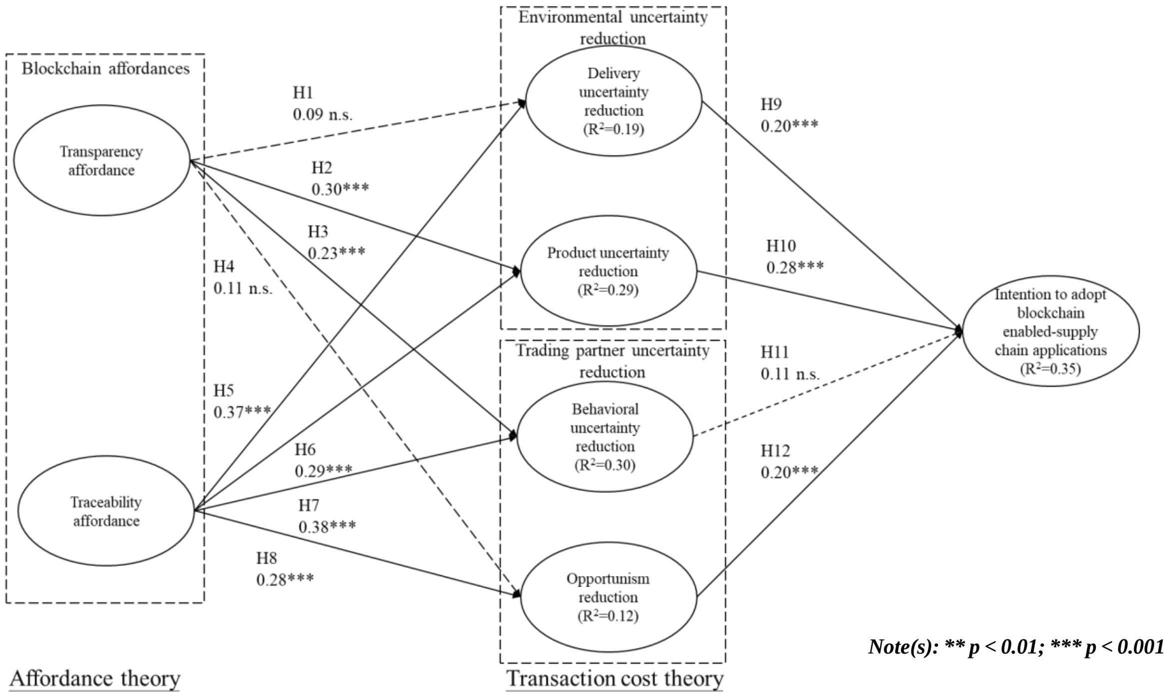

Figure 2. Structural model testing results.

6 Discussion

6.1 Discussion of findings

Despite unprecedented developments in blockchain technology, its adoption rate is relatively low. Therefore, identifying a mechanism by which to support firms' blockchain technology adoption intention is both academically and practically important. Specifically, an empirical understanding of how the technological affordances of blockchain systems affect firms' adoption intention by reducing supply chain uncertainties is still limited. This study yielded several meaningful findings.

First, we found that transparency affordance was influential in reducing product uncertainty and the behavioural uncertainty of trading partners, while its role in reducing delivery uncertainty and opportunism was not significant, thus partially supporting the findings of previous studies (e.g., Aslam et al., 2021; Liang et al., 2021; Shin & Bianco, 2020). This indicates that blockchain enabled supply chain applications with transparency are perceived as being useful in reducing uncertainty about product quality and performance as well as improving understandings between trading partners, such as of goals, operations, and quality control. Our results are also consistent with those of Roeck et al. (2020), who used a case study method, collecting qualitative data from five companies, and found that transparency in distributed ledger technology reduced transaction costs by decreasing uncertainty in supply chain transactions. Obtaining similar results using another research method increases the confidence that the relationship does exist.

Second, we found traceability affordance to play a considerable role in decreasing the transaction cost of business activities by reducing environmental uncertainty, as manifested in delivery and product uncertainty, and trading partner uncertainty, as reflected by behavioural uncertainty and opportunism. Our findings are consistent with prior studies (e.g., Shin et al., 2020; Shin, 2019; Shin & Hwang, 2020), suggesting the importance of traceability affordance and transparency affordance in driving users' satisfaction, as manifested in the reduction of such users' perceptions of uncertainty and opportunism.

Third, we found that although both transparency and traceability affordances reduced the uncertainties of transactions, the extent of their effects differed. Our results showed that traceability affordance had a significant effect on all of the measured uncertainty dimensions, while transparency affordance had a significant effect on only two of the four measured uncertainty dimensions. Moreover, traceability affordance had a stronger effect than transparency affordance on three of the uncertainty dimensions and had a similar effect on product uncertainty. These results were consistent with Joo and Han (2021), who, while not investigating uncertainty reduction specifically, found that traceability had a much greater effect on trust than did transparency. In a review of the literature on blockchain applications (Chang et al., 2022), a network analysis showed that traceability had a stronger connection to blockchain and more strongly drove blockchain adoption than did transparency. This finding has implications for the design of blockchain applications in SCM. Specifically, more resources should be allocated to the implementation of features that enhance the traceability capability of blockchain systems.

Finally, our results showed that of the four types of uncertainty reduced, three exerted a significant effect on the intention to adopt; only behavioural uncertainty did not have a significant effect. Product uncertainty reduction had the strongest effect on the intention to adopt blockchain enabled supply chain applications. Behavioural uncertainty is related more to the internal operations of a firm's partners and whether their processes can be effectively monitored. It seems that companies are concerned more about outcomes, such as the quality and performance of the products in question and whether they can be delivered without any delay or other problems, than the process of producing the products. Therefore, as long as opportunistic behaviours can be reduced by adopting blockchain technology, companies are not as concerned about monitoring the internal operation of their partners.

6.2 Theoretical implications

Blockchain technology may dramatically lower transaction costs and facilitate the removal of the 'middle man' (Cole et al., 2019). A number of researchers have suggested that TCT is a useful theory in understanding the effects of blockchain technology on SCM. However, very few empirical studies have applied TCT in this area, although certain conceptual and theoretical papers have provided insights into this concept (Ahluwalia et al., 2020; Schmidt & Wagner, 2019; Treiblmaier, 2018). For example, Schmidt and Wagner (2019) postulated that blockchain can reduce environmental and behavioural uncertainty. By integrating affordance theory with TCT, our research model contributes to understanding of how blockchain applications affect various dimensions of transactions (e.g., uncertainties) and how the constructs in TCT mediate the effects of blockchain technology affordances.

To the best of our knowledge, we are the first to empirically examine how blockchain technology improves governance efficiency, by integrating affordance theory into the transaction cost model; we thereby answer the call for such research (Ahluwalia et al., 2020; Kummer et al., 2020; Schmidt & Wagner, 2019). Furthermore, drawing on affordance theory, we investigated how supply chain managers interpret what benefits blockchain technology affords and whether these affordances fit their governance goals and facilitate desired outcomes such as reducing environmental and trading partner related uncertainties.

Finally, our findings showed that both transparency and traceability affordances, to different extents, reduced the environmental and trading partner uncertainties of transactions, lending support to propositions developed by other researchers (Ahluwalia et al., 2020; Schmidt & Wagner, 2019) and contributing to the IS and SCM literature.

6.3 Managerial implications

This study provides practical implications for practitioners wishing to promote blockchain technologies to supply chain managers. Our findings revealed that traceability and transparency affordance played considerable roles in decreasing the transaction costs of business activities, which are key factors driving technology adoption intention. As such, practitioners are advised to design user interfaces that enable supply chain managers to trace information and transaction easily. Blockchain enabled supply chain applications should illustrate products' locations and conditions, allowing managers to trace and check the products and helping them to reduce uncertainties in their business transactions.

Furthermore, practitioners are advised to allocate resources to improving the traceability of applications, enabling supply chain managers to trace information on the origin, location, and history of their transactions. Blockchain developers are advised to allocate resources towards creating transparent procedures and information, such as by allowing immutable, distributed ledgers to render transactions transparent, thereby strengthening users' trust in both blockchain technologies and the users' business partners. Finally, blockchain system developers should promote to non-adopters the benefits of blockchain systems' traceability and transparency in reducing uncertainties.

6.4 Limitations and future research directions

This study had certain limitations. First, this was a cross-sectional study that collected data from China, thereby limiting its generalisability to other settings. Future research could replicate the research model using a longitudinal research design to collect data from multiple countries with diverse cultures to enhance the generalisability of the findings. Furthermore, Grover and Malhotra (2003) argued that transaction costs may affect decisions relating to outsourcing, supply chain coordination, and supply chain integration. As lower transaction costs favour markets, a firm adopting blockchain technology may choose outsourcing logistics instead of vertically integrating its operations. This suggests a promising direction of research to investigate how SCM blockchain technology affects firms' choice of governance mode. Moreover, adopting blockchain technology may increase transaction costs, for example, because of the inflexibility of smart contracts. This is worth further investigation. It is important for companies to realise that SCM blockchain applications can affect the transaction costs of their supply chain operations and choose the optimal governance structure accordingly (Murray et al., 2021).

6.5 Conclusion

In summary, our study contributes to understanding of the adoption of blockchain technology in the field of SCM, through TCT. Although the transparency and traceability features of blockchain technology have been extensively studied, their effects on the dimensions of transaction costs in supply chains have received limited scholarly attention. To the best of our knowledge, we are the first to empirically examine how blockchain technology improves governance efficiency, by integrating affordance theory into the transaction cost model; we thus answer the call for research in this direction (Ahluwalia et al., 2020; Kummer et al., 2020; Schmidt & Wagner, 2019). Our findings regarding the respective effects of transparency and traceability affordances on various uncertainties, as well as the respective effects of these uncertainties on managerial intention to adopt blockchain technology, also contribute to the literature on TCT.

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Appendix

Appendix A. Constructs and measurement items

Constructs	Questionnaire items	Sources
Blockchain enabled-supply chain applications offer my firm the possibility to ……,		
Transparency affordance (TRAN)	TRAN1: to transparentize the processes along our supply chain.	(Joo & Han, 2021)
	TRAN2: to provide feedback in the supply chain.	
	TRAN3: to have transparent information about the transactions in the supply chain.	
	TRAN4: to have complete information about the transactions in the supply chain.	
Traceability affordance (TRAC)	TRAC1: to track all items of downstream processes along our supply chain conveniently.	(Joo & Han, 2021)
	TRAC2: to easily trace the location of all items along our supply chain.	
	TRAC3: to easily trace the history of all items along our supply chain.	
	TRAC4: to easily verify all information ranging from the origin of a specified item to its sale along our supply chain.	
	TRAC5: to have a better understanding of how all items of transactions in our supply chain.	
The use of blockchain enabled-supply chain applications……,		
Delivery uncertainty reduction	DUR1: reduces the likelihood of losing delivered product in our supply chain.	(Naiyi, 2004)
	DUR2: reduces the likelihood of delivering the product to a wrong place in our supply chain.	

(DUR)	*DUR3: reduces the use of blockchain enabled-supply chain applications reduces the likelihood of product damaged or contaminated during the delivery in our supply chain.	
Product uncertainty reduction (PUR)	PUR1: makes the quality of the product acceptable in our supply chain. PUR2: makes the product performance consistent with the expectation in our supply chain. PUR3: enhances the product quality in our supply chain.	(Naiyi, 2004)
Behavioral uncertainty reduction (BUR)	BUR1: helps my firm easier to supervise my supply chain partners' operations if needed. BUR2: helps my firm easier to understand my supply chain partners' actions and intentions if needed. BUR3: helps my firm easier to evaluate my supply chain partners' performance on product quality control. BUR4: helps my firm easier to evaluate the achievement of mutual collaborative goals.	(Hsieh et al., 2016)
Opportunism reduction (OR)	OR1: reduces the incentives for my supply chain partners to pursue their interests at the expense of our interests. OR2: makes it difficult for my supply chain partners to alter the facts in order to get what they wanted. OR3: reduces the temptation for my supply chain partners to withhold or distort information for their benefit. OR4: makes it difficult for my supply chain partners to promise to do things and get away without actually doing them later. OR5: reduces my supply chain partners' motivation to take advantage of unspecified or unenforceable contract terms.	(Grover & Malhotra, 2003)
In the next 12 months……,		
Intention to adopt blockchain enabled-supply chain applications (INT)	INT1: the likelihood that my firm would use blockchain enabled-supply chain applications is high. INT2: the probability that my firm would consider using blockchain enabled-supply chain applications is high. INT3: my firm will intend to adopt blockchain enabled-supply chain applications. INT4: my firm will try to adopt blockchain enabled-supply chain applications. INT5: my firm will plan to adopt blockchain enabled-supply chain applications.	(Liang et al., 2021)

*Dropped items

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