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Understanding Managers' Reactions to Blockchain Technologies in the Supply Chain: The Reliable and Unbiased Software Agent

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Abstract

Organizations investing in supply chain information systems struggle to ensure successful adoption and implementation. Projects fail because of technical caveats, inability to meet business needs, and poor management of implementation. Implementation of blockchain technologies across a network of supply chain partners is more complex than internally focused technologies. It is necessary for partner firms to implement, contribute, and share information, and employees to actively use the capabilities of the technology to realize potential. Blockchain technologies can substitute for traditional interfirm intermediaries acting as an unbiased software agent embedded in the supply chain network. Understanding managers' perceptions of and willingness to use blockchain technologies is crucial for successful implementation. Integrating design theory with classic diffusion processes, we conducted a scenario-based role-playing experiment with industry professionals to examine managers' perceptions of blockchain technologies and willingness to use. We find that trustworthiness with regard to competence and perceived distributive justice is the focal drivers of managers' willingness to use the technology. Additionally, both risk and interactional justice are not drivers of willingness to use blockchain technology despite significant claims to that effect. We provide implications for how managers can leverage these drivers to influence supply chain partners' willingness to use the technology.

Keywords: Blockchain; trustworthiness; justice; risk; willingness to use; controlled experiment

INTRODUCTION

Organizations regularly invest in multi-million dollar, multi-stakeholder supply chain information systems and have consistently struggled to ensure a successful adoption and implementation process. For example, Gartner (2017) reported that approximately 75% of all ERP implementation projects fail despite their significant benefits. While some of these multi-million dollar implementation projects fail due to technical caveats or the system's lack of ability to fully meet the specified business needs, others fail because of inadequate implementation process planning and management (Treiblmaier 2018). Effective internal and external implementation process management is required to successfully implement these technological innovations, especially across multi-firm supply chain networks (Hardgrave and Patton 2016). The introduction of technologies into the firm, especially those that are novel, requires strong organizational commitment to the technology and IT within the organization to see optimal success (Steelman et al. 2019).

This implementation process becomes more complicated when exploring technologies that are interorganizational in nature. This includes supply chain systems, which necessitate strong interorganizational collaborations that historically have been problematic to encourage across multiple supply chain partners (Stock and Tatikonda 2008; Bell et al. 2014). Therefore, understanding how managers of supply chain partners perceive and support a new technology is a crucial first step toward understanding the implementation process management and its success (Kim and Kankanhalli 2009). However, understanding why supply chain partners accept or reject a technology has proven to be challenging (Suzuki and Williams 1998; Nyaga et al. 2005).

Blockchain technology is a novel innovation with the potential to reshape interorganizational relations (Pegusapps 2018; Francisco and Swanson 2018; Schuetz and Venkatesh 2019). "Blockchain promises to reshape industries by enabling trust, providing transparency, and reducing friction across business ecosystems" (Gartner, 2018, para. 1). It is an open, distributed ledger technology in which all supply chain partners are granted access directly in a peer-to-peer network to simultaneously exchange immutable records (Durach et al. 2020; Iansiti and Lakhani 2017). Blockchain technology enables authenticated transactions across a *network* of supply chain participants, and as such, the implementation process is much more complex than internally focused organizational technology adoptions. While extant blockchain research primarily focuses on explaining what blockchain technology is, how it functions, and its proposed benefits (Gramoli 2017; Aste et al. 2017; Novo 2018), little is known about the specific aspects of blockchain that actually drive supply chain managers' willingness to adopt and use this technology due to its newness across industries. The proposed informational and transactional benefits of blockchain technologies are only fully realized when all participants in a network are utilizing the system to create a single record of the truth (Iansiti and Lakhani 2017). Therefore, successful implementation and performance of blockchain technologies within the supply chain require significant collaboration and adoption across supply chain partners to define the usage, behaviors, and governance of the system, as well as working collectively to onboard the entire supply chain network onto the system.

This new, shared, collaborative technology implementation has the potential to disrupt many traditional supply chain systems, as

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every trading partner's records are automatically updated and verified in the blockchain system and are viewable instantly by the other supply chain partners. It functions as a transaction record accessible by multiple individuals across multiple firms. Uniquely, the system of permissions and protections mimics those of a reliable, unbiased, and trustworthy software agent, rather than a simple information system that focuses primarily on storing and sharing data (Francisco and Swanson 2018). Blockchain technologies introduce the ability for the system to potentially take on the role of traditional intermediaries (e.g., brokers, banks, import, and export agencies) as an unbiased, automated software agent (Nissen and Sengupta 2006) embedded within the supply chain network.

A software agent is conceptualized as combining the capabilities of different systems (e.g., decision support, expert systems, recommendation systems), resulting in creative applications that can act without bias across all participants in the network (Nissen and Sengupta 2006). In our context, a software agent may be granted authority to make automated decisions about information transmission and financial transactions without traditional intermediaries, which require subsequent audit and intervention from supply chain partners. In the case of blockchain, this embedded software agent acts as a trust generator and a replacement for traditional intermediaries (The Economist 20152015) by ensuring successful and unbiased supply chain interactions and transactions across all partners in the network.

Prior literature on supply chain relationships and their subsequent shared technology implementation has focused on the attributes of the relationship and social perceptions of supply chain partners. In these streams, it has been found that *risk* (e.g., Wagner and Bode 2011; Jia and Zsidisin 2014; Kull et al. 2014; Schwieterman et al. 2018), *trustworthiness* (e.g., Ireland and Webb 2007; Nyaga et al. 2010; Zhang et al. 2011; Sluis and De Giovanni 2016), and *justice* (e.g., Griffith et al. 2006; Tangpong et al. 2010; Griffis et al. 2012; Narasimhan et al. 2013; Welbourne 2018) in the interactions between supply chain partners are core drivers of intentions to interact and transact with others in the network. Prior research has primarily focused on the perceptions of risk, trust, and justice between *organizations* or agents of those organizations. This research takes a novel approach by examining whether *managers* who are agents of supply chain partners exhibit similar perceptions toward blockchain technologies, which may replace traditional organizations that often serve as intermediaries. Thus, we evaluate blockchain as a software supply chain agent and evaluate the potential role of risk, trust, and justice within the network. Therefore, expanding on the previous literature and the uniqueness of blockchain technology as an embedded software agent, this research investigates (*RQ1*) *how blockchain technology features drive manager's willingness to adopt and use this emergent technology within the supply chain,* and *(RQ2) whether these perceptions of risk, trust, and justice mediate the relationship between the blockchain technology and manager's willingness to adopt and use the technology* as in traditional supply chain relationships.

To explore these questions, we use a multi-theoretical approach that integrates design theory and classic diffusion processes to explain how blockchain design features directly and indirectly shape supply chain managers' perceptions of risk, trustworthiness, and justice of adopting and using blockchain technologies within the supply chain network. We examine these questions using scenario-based role-playing experiments (Murfield et al., 2016; Davis-Sramek et al., 2018) to investigate supply chain managers' reactions to the specific features that are inherent in current blockchain implementations and whether they exhibit a willingness to adopt and use the technology over traditional technology designs.

We use a sample of 141 supply chain and IT managers to study their perceptions of four unique experimental scenarios. We find that while blockchain technology features are significant drivers of the perceptions of trust and justice, only specific aspects of trust and justice have direct and mediating impacts on a manager's willingness to adopt and use blockchain technologies. The findings have direct implications for how supply chain partners can present blockchain technologies to their supply chain partners to influence their perceptions of blockchain and ease the implementation process management. Further, the findings also have implications as to how to encourage partner adoption of these technologies, which are claimed to provide increased transparency, trust, and unbiased automation in supply chain transactions.

In the following section, we describe the foundational components of blockchain technologies (i.e., *distributed ledger technologies* and *peer-to-peer networks*) and how they are uniquely combined through cryptography and consensus mechanisms to provide increased functionality for organizational supply chain networks. Next, we briefly review the literature on the classic diffusion process and design theory to explain the theoretical justification for our conceptual model and develop our formal hypotheses for each relationship. Subsequently, the method section details our experimental design, measurement, and sample. Finally, the results section includes a review of the findings from the hypothesis testing and is followed by a discussion of the implications for theory/practice and limitations/suggestions for future research.

BLOCKCHAIN TECHNOLOGIES

We now discuss blockchain technologies and potential operational improvements, and then define two key features of blockchain technologies: distributed ledger technologies and peer-to-peer networks. A blockchain is defined as "a peer-to-peer system for validating, time stamping, and permanently storing transactions and agreements on a shared ledger that is distributed to all participating nodes." (Lacity 2018, p 201).

Blockchains are fundamentally an evolution of database technologies that consist of a novel combination of prior technologies: *distributed ledger technologies* (DLT) that contain a list of append-only, time-stamped transactions backed by *cryptography* and *consensus mechanisms* to ensure security, validity, and permanently store immutable records in a *peer-to-peer network* (P2P). While we have had the separate components (e.g., DLT and P2P) of blockchain technologies for decades (e.g., Jang et al. 2018; Kuhn et al. 2019), it is their unique combination of DLT and P2P networks, protected by the utilization of advanced cryptography and consensus mechanisms, that have propelled blockchain technologies into the next evolution of trusted, fault-tolerant, and secure systems of records that have the potential to dramatically change the way business is conducted globally (Francisco and Swanson 2018).

Many digital interorganizational interactions rely on multiple, disconnected, and centralized systems across trading partners that require much coordination, reconciliation, and trust with participants to ensure fraudulent transactions do not occur across the network (Yermack 2017). To mitigate these problems, many B2B transactions are conducted through trusted third parties (i.e., intermediaries), such as banks or brokers that take on the potential counter-party risk of managing and validating the transactions between two participants in exchange for a portion of transaction cost (Lacity 2018). Blockchain applications promise to fundamentally shift the way organizations interact by removing the need for trusted third parties, instead relying on the algorithmic trust built into the fabric of the blockchain application, which has garnered the name "the trust machine" in popular press (The Economist 20152015). More specifically, blockchain technologies (1) allow participants to interact directly instead of through a third party; (2) eliminate the need for reconciliation due to a shared, time-stamped, and immutable ledger of transactions; (3) instantly provide transparency and provenance of the data of a transaction; (4) settle transactions faster and cheaper by automating transactions and removing third parties; and (5) creating a data structure that is fault-tolerant, resilient, and persistently available to all participants in the network (Lacity 2018).

Next, we describe in detail the two focal components of blockchain technologies, DLT and P2P, and how their unique combination have the potential to create novel transaction systems that enable trust in the system instead of a third party.

Distributed ledger technologies: a single, definitive version of the truth

The first foundational component of blockchain technologies is the use of DLT to store transactions across the entire network of participants. Ledger-based transaction systems have been the foundation of modern business accounting practices that utilize append-only records to a running list of transactions within an organization to allow for in-depth auditing and validation of organizational activities (Francisco and Swanson 2018). DLT takes this technology a step further by providing a digital copy of the entire ledger to all participants in the network, instead of a single, centralized ledger system, to allow for real-time access and a single version of the truth available to all participants. There is no single point of ownership or control of the ledger system, and each participant in the network can verify the records stored in the immutable transaction system (Iansiti and Lakhani 2017).

Peer-to-peer networks for trusted, real-time data

The second foundational component of blockchain technologies is P2P networks, defined as networks that enable communication directly between every participant in the network (Iansiti and Lakhani 2017) instead of through a central participant or multiple, disconnected, one-to-one interactions with a select few participants in the network, such as through existing electronic data interchange (EDI) technologies and networks.

Peer-to-peer networks have the potential to replace traditional business transaction systems by instantly sharing data access and governance, informational resources, and product traceability information in real time across the entire chain, providing equal access and visibility for all network parties instead of only to a limited set of participants. Imagine the conventional information-sharing process within a supply chain where each trading partner manages and controls their own data and information; once a supply chain disruption occurs, the single partner would become a single point of failure for the whole supply chain. Other partners would be unsure whether the already-delayed information they received was accurate or trustworthy. With peer-to-peer networks, any changes in one partner's record would simultaneously be sent and updated in all other partners' systems as well, ensuring complete transparency across the entire process (Werbach 2017).

It is important to note that both DLT and P2P are core to the development of blockchain technologies to allow for a decentralized, peer-to-peer network of participants who are sharing, modifying, and validating a single version of the truth. To enable the security, reliability, and consistency of the DLT across the P2P network, all blockchain technologies utilize some combination of alternative cryptography and consensus mechanisms to check, compare, and validate all new transactions before adding them to the ledger across the entire network (Lacity 2018). Simply put, DLT and P2P are the "what" elements of blockchain technologies, while cryptographic techniques and consensus mechanisms explain the "how." The focus of this research is the fundamental components—DLT and P2P—and not the "how," as most users in a firm need to understand what the technology enables but do not need to be conversant with technical details. It is important, however, for them to understand how the technology can improve processes and provide business value.

The operational improvements from using blockchain technology across a supply chain can be categorized into three areas: supply chain efficiency, consistency, and reachability (Cecere, 2018). Blockchain technology improves supply chain efficiency by providing real-time delivery information and immediate product information, thus facilitating sophisticated practices. An example of improved consistency is in inventory management by synchronizing manufacturers' and buyers' inventory information, thus enabling reduced stock-outs. Reachability is improved by providing a secure path to trade directly with international third-party partners without using intermediaries.

THEORETICAL FOUNDATIONS AND HYPOTHESIS DEVELOPMENT

Prior supply chain and technology implementation literature provides insights into how a firm can prepare for, ramp up knowledge of, and ease adoption and the use of new technologies (Stock and Taikonda 2008). The most common findings in this stream of literature are that participants' *willingness* to adopt and support technologies within the organization is a significant driver of implementation success (Tait and Vessey 1988; McDermott and Stock 1999). Therefore, it is not only the technical attributes of a system that drive its potential adoption and success within the organization, but also managerial perceptions and the willingness to use and support these systems across the organization.

Operations and supply chain researchers have long been aware of the importance of social factors in technology diffusion processes (Williams and Tao 1998; Russell and Hoag, 2004). These social factors refer to the cognitive aspects such as attitude and perceptions of a technology by potential users. The classical technology diffusion process states that adoption of a technology by supply chain managers occurs in three stages—*cognitive, affective, and behavioral* (Rogers 1983; Agarwal and Prasad 1997; Williams and Tao 1998). The cognitive stage describes when a supply chain partner is initially exposed to the potential of a new technology. During this first stage, a supply chain partner evaluates the opportunities of a technology, gains additional knowledge of a technology, and subsequently moves to the second stage—the affective stage. In the affective stage, the attitudes, perceptions, interest, and desire for organizational benefits of the technology are established and set the ground for future adoption behaviors. The behavior stage, or action stage, is where supply chain partners decide to adopt or use a technology. Similarly, technology diffusion theory includes social factors, such as users' perceptions of the innovation, which affect the implementation's success (Russell and Hoag 2003). This perspective has been utilized in a variety of prior technology innovation–diffusion processes, such as EDI, where Suzuki and Williams (1998) concluded that a successful EDI implementation greatly depends on whether a firm can positively influence its supply chain partners' perceptions about the technology and its benefits, and subsequently persuade them to adopt the system.

The conceptual model in Figure 1 presents the classical diffusion process, depicting the three stages (left to right) when a manager is exposed to blockchain technologies, the development of their perceptions of the technology, and their subsequent willingness to adopt and use the technology (Rogers 1983; Agarwal and Prasad 1997). At the first stage (cognitive), a manager is presented with information about blockchain technologies—the blockchain design features of DLT and P2P in this case—and initially becomes aware of this technology and its benefits. The exposure of this information leads to the second stage (affective), where the manager evaluates and generates their own perceptions toward the blockchain technologies.

While the classical diffusion process focuses on social impacts of diffusion through individual perceptions of decision makers within the organization, design theory posits that the exposure to different technological design features can directly affect willingness to adopt and use a new technology due to the inherent technological benefits, or lack thereof, beyond their own perceptions or potential biases (Tanskanen et al. 2015). Using blockchain technology as an example, the attitude of a manager at a supply chain partner could, after being exposed to different blockchain design features, directly shift from the cognitive stage to the behavior stage based on unique features and abilities provided by the technology, as shown in Figure 1.

The focus of this research is to understand how the *blockchain design features* (i.e., DLT and P2P) influence supply chain managers' perceptions and their willingness to use blockchain technologies. Blockchain will not only serve as a technical storage of data across a network, but also act as an automated, embedded software agent that takes the place of existing intermediaries, such as brokers and bankers. Therefore, this research takes a novel approach by examining whether supply chain managers perceive blockchain technologies through the same lens with which they evaluate organizational partners when determining whether to transact. Supply chain partners implementing blockchain technologies will be required to depend on these technologies, much as they do with traditional third-party intermediaries (e.g., brokers and auditors), as an automated agent within the supply chain. More specifically, we examine the three significant drivers of supply chain relationships: perceptions of risk, trust, and justice provided by blockchain technologies and their impact on the willingness to adopt and use the technologies. In the following section, the proposed relationships in our research model (Figure 2) are described and hypothesized.

HYPOTHESES DEVELOPMENT

The effect of blockchain design features on perceived risk in the technology

Kull et al. (2014, p. 470) define perceived risk in a behavioral decision context as *a decision maker's overall assessment of the probabilities and magnitudes of potential losses*. When it comes to open access or sharing their own companies' transaction history through a new technology, managers inevitably perceive these actions as risky, especially in the case of novel and

Figure 1: Conceptual model.

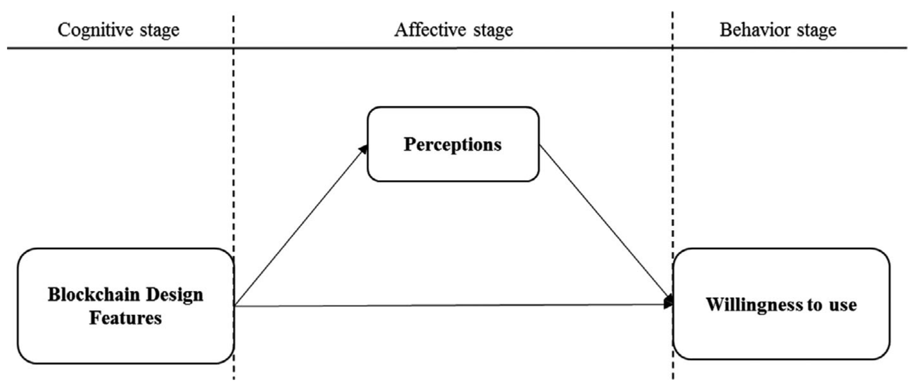
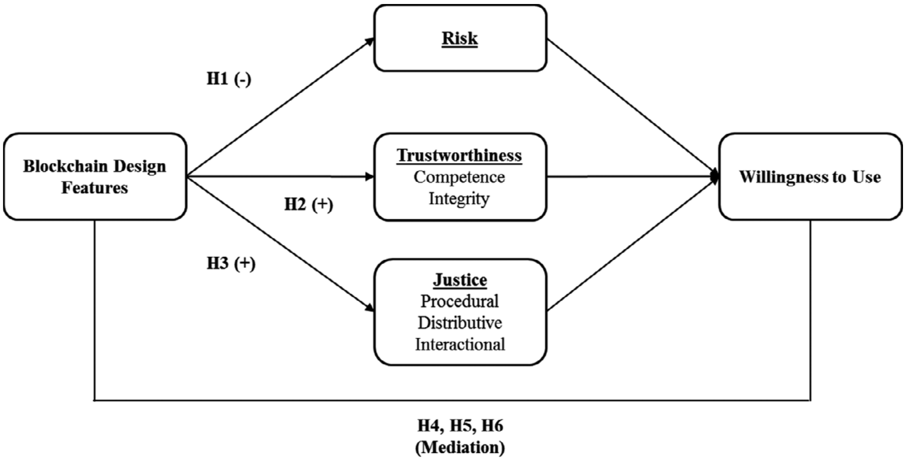


Figure 2: Research model.



emergent technologies. While prior technologies using shared data structures have inherent risk due to a lack of control of the data and systems, the magnitude of such risk can be significantly diminished when using blockchain technologies because it serves as an embedded software agent with defined rules, policies, and behaviors. A distributed ledger lowers the probability, and magnitude of potential losses during information transmission by ensuring transaction records is immutable and accessible despite potential partner network outages. A supply chain partner falsifying or changing prior transactions is easily traced to a specific record due to embedded blockchain consensus mechanisms. Direct P2P communication between supply chain partners will grow visibility and transparency between those partners by increasing data access, ensuring transactional obligations, and providing ongoing monitoring of all network transactions. We hypothesize that, when presented with the scenario regarding blockchain technologies, supply chain managers will perceive blockchain as less risky.

> ***H_1*. *Blockchain design features have a direct negative effect on managers' risk perceptions.***

The effect of blockchain design features on perceived trustworthiness of the technology

Extant literature regarding buyer–supplier relationships provides evidence that trust plays a major role in successful interorganizational collaboration activities (Corsten and Kumar, 2005; Nyaga et al., 2010). Decision-making and information system researchers point out the major role that innovative technologies play in developing trust (Wang and Benbasat, 2007). The phenomenon of trust has evolved to be trust between individuals and between individuals and their technology (Wang and Benbasat, 2005; Komiak and Benbasat, 2006). The literature examining trust in technologies has focused on the concept of trustworthiness (Vance et al., 2008). Unlike trust, which is demonstrated by the behaviors of the trustor, trustworthiness is demonstrated by the trustee. The technology can seem to exhibit certain behaviors and adherences to behaviors that engender trust. The implementation of specific technology design features can significantly influence perceived trustworthiness when design features are provided to deliver both visibility and transparency of behaviors across the supply chain network.

Trustworthiness of the technology can be divided into two types: competence and integrity of the technology (Vance et al. 2008; Colquitt and Rodell 2011). *Trustworthiness–competence* reflects the confidence in a technology to perform its intended behaviors without flaws or inconsistencies (Vance et al. 2008). With current information technologies, firms have difficulty performing some operational tasks, such as tracking the detailed history of a product, due to the lack of visibility and transparency of the transactions across the supply chain (Hardgrave et al. 2013; Popper and Lohr 2017). Blockchain features enable a cross-party, real-time shared ledger with an unchangeable history of transactions that can be trusted due to the immutability and validation embedded into the technology. For example, it is reported that it takes two months, on average, to track down the source that causes a salmonella outbreak in the United States (U.S. FDA 2017). In contrast, Walmart, by using blockchain technologies, was able to track which farms produced contaminated mangos in only 2.2 seconds. It previously took at least one week (Roberts 2017).

Trustworthiness–integrity reflects whether a technology adheres to a set of accepted principles or rules. Blockchain, as an embedded software agent, permanently records, verifies, and distributes transactions in real time based on the specific processes that are encoded into the system. As blockchain technologies will only perform the behaviors that are encoded, defined, and applied by its designers, it essentially functions as an unbiased information coordinator, data governor, and accountant across the end-to-end supply chain that will only perform the tasks designed. Because traditional third parties—such as banks, brokers, and other organizations—are driven by human interventions, there is the potential for opportunism, favoritism, and biases. The utilization of a blockchain technology as an embedded software agent to replace traditional third parties gives supply chain partners further confidence in the integrity of the system and the behaviors that other partners perform.

Many traditional information systems utilized across a supply chain typically involve multiple, disconnected, and centralized databases that are managed and controlled by each individual actor. This disconnection in the management, validity, and transparency of critical supply chain data can lead to significant potential for fraud, opportunism, and bias in supply chain transactions. Fraud within supply chains is a significant concern for organizations and their consumers alike, as a lack of visibility and transparency significantly hinders the ability to identify and address fraudulent behavior. Recently, Alibaba Group and its Australian partners decided to explore the use of blockchain to combat food fraud. Their research indicates that blockchain technologies will provide greater transparency between buyers and sellers, and shipping information could be tracked in real time and shared across supply chains (Alizila 2018), increasing accountability and reducing the risk of fraud. We hypothesize that the use of blockchain technologies will increase the visibility and transparency of behaviors across the supply chain network and increase perceptions of the trustworthiness of the competence and integrity in the technology.

> ***H_{2a}***. *Blockchain design features have a direct positive effect on managers' trustworthiness–competence.*
> ***H_{2b}***. *Blockchain design features have a direct positive effect on managers' trustworthiness–integrity.*

The effect of blockchain design features on the perceived justice of the technology

In scenarios that have the potential to be wrought with fraud, bias, and opportunism, the perceived justice in the technology and the processes it enables are a critical, yet complex conduit that has the potential to enable collaborative behaviors (Nyaga et al. 2010). Research evidence shows that even when a buyer and supplier collaborate and share information and processes, with both receiving benefits from the collaboration, the suppliers may still have a greater feeling of inequity in the relationship (Corsten and Kumar 2005; Tangpong et al. 2010). The perceived justice embedded within the supply chain network enables members to work together, share strategic goals, and succeed as a team without worrying about the opportunism, bias, and fraud that other partners in the network may exhibit. A successful supply chain is built on cooperation and collaboration, which is facilitated if partners have the same understanding and fairness of outcomes of the procedures involved in managing the relationship (Hofer et al. 2012). Typically, research has examined the perceived justice as enforced by the supply chain partners and their unique relationships; however, in the context of blockchain technologies, the fair distribution of outcomes and procedures can be enforced as an embedded software agent that performs only the duties it was designed to execute without bias or opportunism. Blockchain technology enables data standardization, visibility into real-time information across the supply chain, and embedded processes that are agreed on by the supply chain partners that are monitored, tracked, and enforced equally across the supply chain. We specifically investigate the impact of blockchain design features on enabling three types of justice: *procedural, distributive, and interactional*.

Procedural justice is defined as the perceived fairness of policies and procedures associated with the distribution of outcomes or rewards (Greenberg 1990; Griffith et al. 2006). Bunker and Rubin (1995) described four elements that characterize procedural justice. First, a fair procedure emphasizes consistency. Second, those carrying out the procedure must be impartial and neutral. Third, those directly affected by the decisions should have a voice in representing themselves in the process. Lastly, the processes that are implemented should be transparent. In reality, few organizations and technologies have been able to fulfill procedural justice. For example, the Federal Acquisition Regulation (FAR), founded in 1974, provides uniform policies and procedures for acquisitions to ensure fairness and openness in federal procurement. However, for more than 40 years, FAR has struggled to ensure procedural justice, even after implementing numerous guidelines and support systems. The dependence on conventional technologies "caused delays in awarding contracts, threatening the promise of fairness and openness in federal procurement" (Nayak and Nguyen 2018). In 2017, the U.S. General Services Administration (GSA), the world's largest buyer, built the first federal procurement blockchain proof of concept and reduced the time to award contracts from 100 days to less than 10 days (U.S. GSA 2017). By automating processes with blockchain technologies through embedded software agents, collaborators will be able to enhance the consistency of the processes, remain unbiased across all supply chain partners, ensure equal representation, and provide increased transparency in the entire network. We hypothesize:

> ***H_{3a}***. *Blockchain design features have a direct positive effect on managers' perceptions of procedural justice.*

Distributive justice is defined as the content of fairness that focuses on the fairness of outcome distributions and partner contributions (Hofer et al. 2012; Tang and Sarsfield-Baldwin 1996; Greenberg 1990). Folger and Konovsky (1989) likened procedural and distributive justice to "how" and "what." The "how" is equivalent to the fair rules, processes, and patterns that make up procedural justice. The "what" relates to the fair distribution of specific resources, goods, and assets. Using the U.S. GSA example again, the current system has limited transparency for the external suppliers to determine the fairness of the contract awards. However, with the recent blockchain proof of concept, every transaction is stored on the blockchain's distributed ledger, and the supply chain partners are no longer left in the dark in regard to the awarding of contracts. Each supply chain partner receives a fair distribution of information resources, allowing them to check offer statuses, contract completions, and monitor awarded contracts to ensure equal distribution of outcomes across the supply chain. The use of blockchain technologies has the potential to provide significant benefits to supply chain partners through increased visibility and transparency, which will ensure the equal and unbiased distribution of outcomes. We hypothesize:

> ***H_{3b}***. *Blockchain design features have a direct positive effect on managers' perceptions of distributive justice.*

Interactional justice is the third type of perceived justice and focuses on aspects of the day-to-day communication/interaction processes that refer to the degree to which the partners perceive equality and fairness (Narasimhan et al. 2013). Although digital information sharing is not uncommon in the United States, many trading companies from other countries are not as advanced. For example, the Danish shipping company Maersk has been looking for a better way to trace its shipments worldwide and reduce the piles of paperwork required for each container (Kshetri 2018). When there is a disagreement, someone must go through the paper files and create a history of events. This is inefficient, time-consuming, and rife with human error. Paper records can easily be altered or lost, resulting in further disagreements and shipment delays. Maersk's study found that a simple cross-border shipment of refrigerated goods can go through "nearly 30 people and organizations, including more than 200 different interactions and communications" (Groenfeldt 2017, p. 1).

The implementation of blockchain technologies provides a series of benefits above and beyond simple digitization of the process (Blakstad and Allen 2018; Mendling 2018). While digitization provides the potential for reduced human errors, it does not ensure visibility and transparency unless the information is shared across the supply chain. Blockchain technologies guarantee that all relevant transactions performed in the network are both visible and transparent across the entire network. Therefore, interactions between specific partners are performed as expected and consistently. Additionally, the use of an embedded software agent through blockchain-enforced transactions and processes will reduce human errors, bias, and potential fraud between interactions of the supply chain partners. We hypothesize:

H_{3c}. *Blockchain design features have a direct positive effect on managers' perceptions of interactional justice.*

The mediating effects of perceptions on the willingness to use blockchain technologies

The classic diffusion process states that perceptions have a direct causal relationship with potential users' willingness to use a new technology (Rogers 1983; Agarwal and Prasad 1997; Williams and Tao 1998). Russell and Hoag (2004) illustrate how understanding perceptions factors into complex information technology decisions that are imperative for successful implementations. Their results indicate the importance of considering perceptions when attempting to reverse the growing trend of costly technology implementation failures. Rogers' work (1983) describes the innovation–diffusion process as an information-gathering process. Information about the existence of the innovation, as well as the innovation's features and characteristics, flows through the social system, which generates perceptions (Agarwal and Prasad 1997). The specific features of a technology have been shown to be important drivers of willingness to use the technology by altering key user perceptions (Moore and Benbasat 1991; Davis 1989; Saga and Zmud 1993).

The extant literature shows that increased risk perceptions are associated with decreased risk-taking behavior (e.g., Kull et al. 2014). Since we propose that, traditionally, using shared information technologies could result in potential losses or other negative outcomes, we argue that perceived risk will have a negative influence on willingness to use. It is known that supply chain partners are not afraid to share information if the relationship is based on trust (e.g., Sluis and De Giovanni 2016). Similarly, we argue that with increased trustworthiness of the technology (competence and integrity), supply chain agents will be more willing to use blockchain and make themselves vulnerable to potential harm. Finally, procedural, distributive, and interactive justice is known to have positive influences on supply chain relational behaviors (e.g., Griffith et al. 2006; Narasimhan et al. 2013). We argue that people engage in reciprocal behavior when they perceive fair procedures, fair distribution of resources, and egalitarian information-sharing processes associated with blockchain technology. We hypothesize:

H_4. *Risk mediates the effect of blockchain technology on managers' willingness to use.*
H_{5a}. *Trustworthiness–competence mediates the effect of blockchain technology on managers' willingness to use.*
H_{5b}. *Trustworthiness–integrity mediates the effect of blockchain technology on managers' willingness to use.*
H_{6a}. *Procedural justice mediates the effect of blockchain technology on managers' willingness to use.*
H_{6b}. *Distributive justice mediates the effect of blockchain technology on managers' willingness to use.*
H_{6c}. *Interactional justice mediates the effect of blockchain technology on managers' willingness to use.*

METHOD

Our research objective was to examine the effects of blockchain design features on supply chain managers' perceived risk, trustworthiness, and justice of the technology, and subsequent willingness to use blockchain technologies. To examine the hypotheses, we conducted a scenario-based survey experiment with manager participants from leading U.S. firms. In a between-subject 2 (*DLT: with vs. without*) × 2 (*P2P: with vs. without*) experimental design, participants were randomly assigned through the Qualtrics survey software to one of four treatment conditions. Each treatment group was systematically given alternative descriptions of the technology design features (see the appendix for the complete text for each vignette scenario) where the *with DLT and with P2P* treatment served as the blockchain scenario. The alternative three scenarios represent alternative configurations of existing technologies without at least one of the core components of DLT or P2P.

The scenario-based experiment provides a valuable opportunity to understand the nuances of decision making (Eckerd and Bendoly 2011; Knemeyer and Naylor 2011). The vignette methodology is frequently used to assess decision-making behavior in the operations and supply chain management field (e.g., Mir et al. 2017; Reimann et al. 2017). There are numerous advantages to using a scenario-based experiment. For example, in the field, it is difficult to measure all characteristics of suppliers and the influence of blockchain because most companies have limited knowledge of and experience in the technology due to its novelty and relative immaturity (Gartner 2018). With the scenario-based experiment, controlling information and capturing individual-level perceptions and willingness are feasible, and the results provide insights into the specific information that may impact managerial perceptions of the technology.

Table 1: Measurement items, loadings, and reliabilities

Measures	Item description	Cronbach's alpha/standardized loading	
Willingness to use (Taylor and Todd, 1995)	**WU1**: I intend to use this technology design.	.92	.96
	WU2: I intend to use this technology design for work projects.		.93
	WU3: I intend to use this technology design frequently if my company implements it.		.79
Perceived risk (Kull et al., 2014)	**PR1**: There seems to be a lot of risk in using this technology design.	.95	.91
	PR2: There is high risk in the decision of whether to use this technology.		.92
	PR3: This technology design can be characterized as risky.		.94
Trustworthiness–competence (Vance et al., 2008; Colquitt and Rodell, 2011)	**TC1**: This technology design has the capability to perform the required job.	.77	.64
	TC2: I feel confident about this technology design.		.88
	TC3: This technology design has specific capabilities that can increase our performance.		.62
Trustworthiness–integrity (Vance et al., 2008; Colquitt and Rodell, 2011)	**TI1**: The input and output of this technology design are consistent.	.88	.74
	TI2: This technology design will help to ensure that all trading partners keep their promises.		.77
	TI3: This technology design allows for dealing with all trading partners fairly.		.89
	TI4: I like the values incorporated in this technology design.		.82
Procedural justice (Hofer et al., 2012)	**PJ1**: This technology design includes fair policies for all trading partners.	.94	.89
	PJ2: This technology design treats all trading partners fairly.		.95
	PJ3: This technology design is equitable in its treatment of all trading partners.		.93
Distributive justice (Hofer et al., 2012)	**DJ1**: This new technology design requires that all trading partners to contribute.	.93	.82
	DJ2: All trading partners must contribute to the business relationship when using this technology design.		.92
	DJ3: The outcomes or rewards we receive, if using this technology design, will be fair.		.91
	DJ4: The outcomes or rewards our trading partners receive, if using this technology design, will be fair.		.89
Interactional justice (Narasimhan et al., 2013)	**IJ1**: This technology design will assist us in resolving any disagreements quickly.	.78	.74
	IJ2: This technology design allows us to exchange information in a timely manner.		.66
	IJ3: This technology design keeps trading partners informed of any changes that may affect others.		.80
Perceived usefulness (Venkatesh et al., 2012)	**PU1:** I find this technology design useful for my work.	.93	.91
	PU2: Using this technology design will help me accomplish things more quickly.		.95
	PU3: Using this technology design will increase my productivity.		.96
Personal innovativeness (Jackson et al., 2013)	**PI1:** If I hear about a new information technology, I would look for ways to experiment with it.	.86	.87
	PI2: Among my peers, I am usually the first to try out new information technologies.		.88
	PI3: I like to experiment with new information technologies.		.92
Previous knowledge (Anwar et al., 2017)	**PK1:** I had formal training on using blockchain.	.70	.63
	PK2: The organization I work for has an established blockchain system.		.88
	PK3: The organization I work for has provided employees with information about blockchain.		.82

Sampling frame

Participants were business managers who were obtained from two information system conferences and an information system association in the United States. The majority of the respondents were supply chain managers (34.8%) and information technology managers (44%). We received 258 responses in total—of which 180 completed all the questions. We then removed 39 responses that failed the attention checks. The final sample provided 141 usable responses out of a total of 258. This yielded an average of 35 participants per treatment cell. The average age of participants was 40.3 years old, and they averaged 4.11 years of work experience with their present firm, and 51.8% were female.

Stimulus material

Participants were asked to carefully read the vignette and imagine themselves as a supply chain manager who recently had a conversation with a retail customer. The customer suggested that the manager's company should use an unnamed "new technology design." Our design of the scenario vignettes specifically ensured that the term "blockchain" was not mentioned in the scenario in order to eliminate potential personal biases toward blockchain, which has seen significant press coverage in the past few years. The stimulus material consisted of the four different scenarios: a description of the "new technology design" with (1) both DLT and P2P, (2) with DLT only, (3) with P2P only, or (4) with neither feature. After reviewing the scenario, each participant answered questions in regard to the technology design presented and their willingness to use it.

Measures

Previously validated scales were used or adapted for each of the constructs. All constructs were multi-item, 7-point Likert scales (1 = strongly disagree; 7 = strongly agree), and each item was slightly modified for the context of this research. The constructs with the original source, and the scale items, loadings, and reliabilities are presented in Table 1.

Note that our contextualization focuses on the technology and not on the supply chain partner or retailer—in line with prior research examining, for example, trust in technology artifacts (Wang and Benbasat 2007). In addition to our focal variables, a series of control variables were utilized to rule out differences across individuals and their perceptions of the technology design's functionality. In addition to individual attributes, such as a participants *age*, *gender*, *years in their current company*, and *years in their current position*, we captured *perceived usefulness* of the technology design (Venkatesh et al. 2012), *previous knowledge and experience with blockchain technologies* (Anwar et al. 2017), and *personal innovativeness with IT* (Jackson et al. 2013) due to their predictive power in prior research on technology use. Following the sequence commonly used in behavioral experiments (see Perdue and Summers, 1986), all individual-level control variables were collected after all other variables that were central to the experiment, avoiding the possibility that the participants might be influenced by these control variables. Table 2 details the summary statistics and correlations of the measures used in this study.

RESULTS

Construct validity and reliability

Confirmatory factor analysis (CFA) was used to assess internal consistency, as well as the convergent and discriminant validity of the measurement instruments, using AMOS 22.0. The CFA produced adequate fit statistics of $chi^2 = 709.83$, df = 419, comparative fit index (CFI) = 0.92, and root-mean-square error of approximation (RMSEA) = 0.07 (Thompson 2004). Internal consistency, as measured by Cronbach's alpha, is reported with values of 0.70 or above generally deemed acceptable (Fornell and Larcker 1981). As presented in Table 1, internal consistency was sufficient across all samples, with Cronbach's alphas ranging from 0.70 to 0.95.

To examine the convergent and discriminant validity of the constructs, we examined the standardized loadings of each item (see Table 1), which provided significant loadings on the focal constructs and limited cross-loadings. Additionally, the average variance extracted (AVE) from each construct in Table 2 exceeded the recommended threshold of 0.50 (Hair et al. 2006), with the lowest value of 0.61. The square root of the AVE, provided on the diagonal in Table 2, exceeds all off-diagonal correlations, indicating further discriminant validity (Fornell and Larcker 1981). Based on the CFA, we find evidence that the measurement instruments were consistent and exhibited adequate convergent and discriminant validity.

Randomization and manipulation checks

Randomization is an essential procedure in our experimental design, as it is expected to control for the impact of alternative explanatory variables on the treatment groups, such as previous knowledge and experience with blockchain technologies (Bachrach and Bendoly 2011). To guarantee the participants do not have significantly different levels of knowledge of blockchain technologies, we measured each participant's previous knowledge at the end of the survey questionnaire. Participants had a mean of 2.81 on our 7-point scale for previous knowledge and experience with blockchain technologies, indicating limited exposure to these emergent technologies. Further, the results did not show a significant difference in prior knowledge and experience with blockchain technologies ($F = 1.74$, $p > .05$), personal innovativeness ($F = .85$, $p > .05$), years in the company ($F = 1.10$, $p > .05$), or years in their role ($F = 1.37$, $p > .05$) across the different treatment groups, providing further evidence of randomization in this study.

To assess whether participants were aware of their respective experimental manipulations concerning the disclosure of blockchain design features, we included four manipulation check questions that were measured on a 7-point Likert scale (1 = strongly disagree; 7 = strongly agree). We asked the participants to select the specific features that were mentioned in their vignette scenario to ensure they recognized the primary manipulations of the vignette. Specifically, the question states: "This new technology design contains the following features (strongly disagree – strongly agree): verifiable records; permanent records; synchronized communication; real-time data transmission."

Table 2: Descriptive statistics and correlation matrix

Variables	Mean	SD	AVE	TC	TI	PJ	DJ	IJ	Risk	Will.	PU	PI	PK	Age	GND	Co.	Pos.
Trustworthiness–competence (TC)	4.56	1.13	0.72	**0.85**													
Trustworthiness–integrity (TI)	4.36	1.46	0.80	0.61**	**0.97**												
Justice–procedural (PJ)	4.92	1.51	0.92	0.50**	0.74**	**0.98**											
Justice–distributive (DJ)	4.28	1.37	0.88	0.70**	0.64**	0.69**	**0.98**										
Justice–interactional (IJ)	4.79	1.54	0.73	0'.61**	0.39**	0.34**	0.48**	**0.96**									
Risk	4.69	1.44	0.92	−0.53**	−0.51**	−0.41**	−0.50**	−0.19*	**0.98**								
Willingness (Will.)	4.18	1.54	0.89	0.69**	0.62**	0.56**	0.70**	0.45**	−0.49**	**0.98**							
Perceived usefulness (PU)	4.39	1.30	0.88	0.71**	0.45**	0.36**	0.64**	0.51**	−0.46**	0.53**	**0.98**						
Personal innovativeness (PI)	4.95	1.15	0.79	0.18*	0.12	0.05	0.14	0.06	−0.02	0.03	0.07	**0.97**					
Previous knowledge (PK)	2.81	1.40	0.61	−0.02	−0.10	−0.15	−0.11	−0.01	0.12	−0.08	−0.04	0.22	**0.94**				
Age	40.28	12.58		−0.01	0.03	0.07	0.12	0.12	−0.18*	0.14*	−0.06	−0.15	−0.17*	**N/A**			
Gender (GND)	0.48	0.50		0.02	0.14*	0.07	−0.02	−0.01	−0.09	0.00	−0.04	0.23**	−0.13	0.02	**N/A**		
Year in current company (Co.)	4.11	2.37		−0.14	−0.06	0.03	−0.04	0.00	−0.06	0.04	−0.12	−0.18*	−0.08	0.46**	−0.09	**N/A**	
Year in current position (Pos.)	1.38	1.42		0.00	0.07	0.03	−0.02	0.04	−0.16*	0.07	−0.05	−0.13	−0.08	0.48**	−0.02	0.53**	**N/A**

Note.: Square root of the AVE on the diagonal; female coded as 0; male coded as 1.
n = 141.
*$p < .05$,
**$p < .01$.

Specifically, managers in the scenarios that contain DLT reported higher scores on verifiable records (M = 6.32, F = 102.98, $p < .001$) and permeant records (M = 6.32, F = 27.35, $p < .001$) than the scenarios that do not have this treatment (M = 3.16; M = 2.28), as expected. Also, managers in the scenarios that contain P2P have higher scores on real-time data transmission (M = 6.53, F = 35.64, $p < .001$) and synchronized communication (M = 6.52, F = 28.25, $p < .001$) than the scenarios that do not have this treatment (M = 3.76; M = 3.92), as expected. Therefore, the results show a significant difference across the scenarios that include DLT (verifiable records and permanent records) and P2P (synchronized communication and real-time data transmission), such that participants understood and recognized the manipulations.

Analysis

To test the hypotheses, we conducted a multiple mediation analysis to analyze the direct, mediated, and total effects of the blockchain design features on managers' willingness to use the technology (Hayes 2013; Lecheler et al. 2015). Specifically, we created a dummy variable for the blockchain scenario (with DLT and P2P) coded as 1 and the remaining three scenarios as 0 for our path analyses and compared each scenario separately in plotting their effects. The results of this analysis are presented in Figure 3.

The effect of blockchain design features on risk, trustworthiness, and justice

To begin, we examine the impact of the blockchain design features on the managers' perceptions of risk, trustworthiness, and justice. The results in Figure 3 indicate that the blockchain scenario does not have a significant effect on *risk* ($b = -.06$, $SE = .08$, $p > .05$). Although the coefficient direction is consistent with the predicted relationship direction, that is, managers perceive less risk with the introduction of blockchain features. Therefore, $\mathbf{H_1}$ is not supported. Nevertheless, we found significant positive effects on *trustworthiness–competence* ($b = .20$, $SE = .06$, $p < .001$) and *trustworthiness–integrity* ($b = .35$, $SE = .07$, $p < .001$) and predicted 57% and 35% of the variance, respectively. Therefore, $\mathbf{H_{2a}}$ **and** $\mathbf{H_{2b}}$ are supported. Further, we found significant positive effects on *procedural justice* ($b = .27$, $SE = .08$, $p < .001$), *distributive justice* ($b = .24$, $SE = .07$, $p < .001$), and *interactional justice* ($b = .35$, $SE = .07$, $p < .001$) and predicted 22%, 60%, and 39% of the variance, respectively. Therefore, the results also support $\mathbf{H_{3a}}$, $\mathbf{H_{3b}}$, **and** $\mathbf{H_{3c}}$.

To further understand the effect of each blockchain feature, we plotted the means of each construct for each vignette scenario. The results, shown in the appendix in **Figures A1-A7**, follow the expected proposed hypothesized relationships such that the blockchain scenario, compared with scenarios not using these features, has the highest level of willingness to use (Figure A1), provides increased trustworthiness in the competence ($\mathbf{H_{2a}}$, Figure A3) and integrity ($\mathbf{H_{2b}}$, Figure A4) of the technology, as well as increased procedural ($\mathbf{H_{3a}}$, Figure A5), distributive ($\mathbf{H_{3b}}$, Figure A6), and interactional ($\mathbf{H_{3c}}$, Figure A7). Additionally, we find that the blockchain scenario indeed provides lowered risk, especially compared with the scenarios that do not include a

DLT; however, the inclusion of P2P actually slightly increased the perceived risk, compared to those not using peer-to-peer networks, although the difference is not significant (SE = .32, $p > .05$.). After identifying the direct effects of our focal constructs (**H_1–H_3**), in the following section we examine the mediating effects of the blockchain design features on willingness to use blockchain technologies (**H_4–H_6**) through managers' perceptions to determine the mechanisms driving their willingness to use.

The mediating effects of risk, trustworthiness, and justice on willingness to use

To examine the mediated effects of the blockchain design features on willingness to use through managers' perceptions (risk; trustworthiness–competence and integrity; and justice–procedural, distributive, and interactional), we examined the overall effects utilizing the Hayes (2013) process for testing multiple mediators. The results of this analysis were tested using a bootstrap estimation approach with 5,000 samples in Table 3 for the direct, mediated, and total effects of the blockchain scenario on willingness to use.

Following Hayes (2013), we began by examining the total effect of blockchain design features on willingness to use (i.e., the effect of blockchain design features on willingness to use without the presence of any mediating effects) and found a positive and significant effect (b = .28, SE = .07, 95% CI = [.1494, .4357]). Next, we examined the complete model, as shown in Figure 3, which includes both the direct and mediated effects of blockchain design features on willingness to use. Figure 3 indicates that when examining all mediators together in a single model, the direct effect of blockchain design features on willingness to use in the presence of mediators becomes nonsignificant (b = .07, SE = .07, $p > .05$.), indicating full mediation through the identified managers' perceptions. Specifically, we see that the blockchain design features indeed affect managers' perceptions, but perhaps more importantly, that not all these perceptions function as mediators of the effects on willingness to use, indicating which mechanisms should be leveraged in changing a partner's willingness to use the technology. Given the lack of a direct effect of the blockchain scenario on risk and risk's subsequent nonsignificant effect on willingness to use blockchain technologies (b = −.06, SE = .08, $p > .05$.; indirect effect of blockchain features: b = .01, SE = .01, 95% CI = [−.0104, .0290]), we find no indication of a mediation effect, and therefore, the results do not support **H_4**. Alternatively, exposure to the blockchain scenario had a positive effect on trustworthiness–competence (b = .20, SE = .06, $p < .001$), which was positively related to willingness to use (b = .36, SE = .10, $p < .001$; indirect effect of blockchain features: b = .07, SE = .03, 95% CI = [.0208, .1346]), indicating a mediation effect and supporting **H_{5a}**. We also find a significant direct effect of the blockchain scenario on trustworthiness–integrity (b = .35, SE = .07, $p < .001$); however, there is no effect of trustworthiness–integrity on willingness to use (b = .15, SE = .10, $p > .05$; indirect effect of blockchain features: b = .05, SE = .04, 95% CI = [−.0125, .1230]), indicating no mediation and, therefore, not supporting **H_{5b}**.

When examining aspects of perceived justice, exposure to the blockchain scenario increased the perceived procedural justice (b = .27, SE = .08, $p < .001$), but we did not find a significant relationship between procedural justice and willingness to use (b = .04, SE = .09, $p > .05$.; indirect effect of blockchain features: b = .01, SE = .03, 95% CI = [−.0357, .0669]), indicating no mediation and not supporting **H_{6a}**. Alternatively, there was a positive effect on distributive justice (b = .24, SE = .07, $p < .001$), and distributive justice was positively related to willingness to use (b = .30, SE = .10, $p < .001$; indirect effect of blockchain features: b = .07, SE = .03, 95% CI = [.0277, .1502]), indicating mediation and supporting **H_{6b}**. Finally, while we find a significant impact of the blockchain design features on interactional justice (b = .35, SE = .07, $p < .001$), we find no effect of interactional justice on willingness to use (b = −.02, SE = .08, $p > .05$; indirect effect of blockchain features: b = −.01, SE = .03, 95% CI = [−.0595, .0518]), indicating no mediation and not supporting **H_{6c}**.

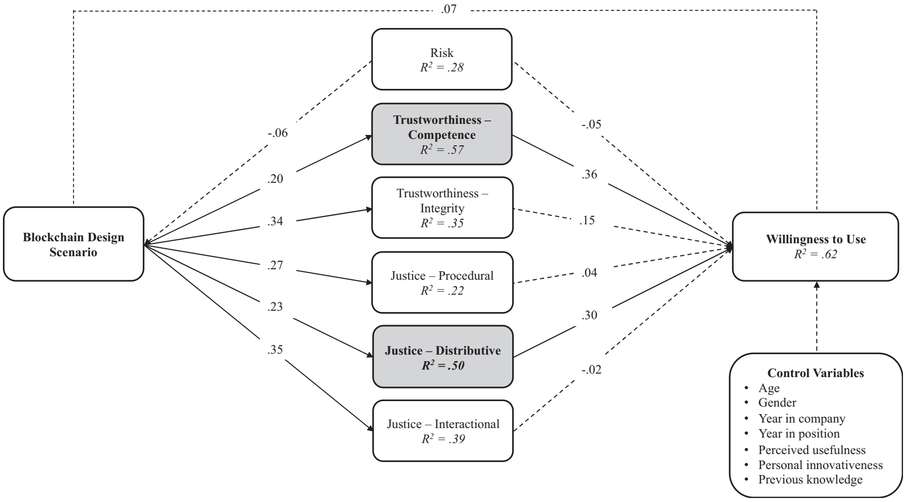
In testing the level of mediation these technology perceptions have on the blockchain design features effect, we found evidence of a significant total effect (i.e., effect without the presence of mediators) and subsequently a loss of significance when examining the holistic model (i.e., effect with the presence of mediators) providing evidence of mediation in our model (Hayes 2013). More specifically, we find that the effect of the blockchain design features on willingness to use was fully mediated by trustworthiness–competence and distributive justice when examined in our holistic model, indicating the primary mechanisms by which willingness to use the technology is affected. Before discussing the specific implications of these findings, we conducted a series of robustness tests to examine the strength of the mediation for each mechanism, as well as the potential impact of the term "blockchain" in our results.

Robustness checks

We conducted additional checks in order to ensure the robustness of our experimental design and the main analysis results. First, we conducted an additional mediation analysis with a single mediator at a time in order to isolate the effects of each mediator. Consistent with the main analysis, the results show that perceived risk and interactional justice remain as statistically nonsignificant mediators (b = .02, SE = .02, 95% CI = [−.0179, .0645]; b = .04, SE = .03, 95% CI = [−.0125, .1142]; respectively). However, trustworthiness–integrity and procedural justice were seen as statistically significant mediators when examined independently (b = .15, SE = .04, 95% CI = [.0807, .2341]; b = .10, SE = .03, 95% CI = [.0377, .1690], respectively). As the dimensions of trust or justice may theoretically be related (Bidarian and Jafari, 2012), some level of correlation between the dimensions may suppress these mediating effects despite our VIFs remaining below 2.69. Therefore, these results imply that trustworthiness–integrity and procedural justice are weaker mediators between the blockchain design features and willingness to use, compared with the primary drivers of trustworthiness–competence and distributive justice.

Next, we conducted a post hoc data collection to examine the potential biases that may exist due to the increased discussion of blockchain in the media. We collected a second sample of 69 participants from similar conferences and conducted an additional

Figure 3: Multiple mediation model for the blockchain design features.Mediation model for the indirect effect of the blockchain design features on willingness to use through perceptions of risk, trustworthiness, and justice. Standardized coefficients are presented for each path examined. Significant paths are solid lines ($p < .001$); nonsignificant effects are dashed lines. Significant mediators are indicated in bold. The direct effect of blockchain design features on willingness to use in the presence of mediators is nonsignificant and thus completely mediated through trustworthiness–competence and justice–distributive.



analysis to compare across two alternative scenarios utilizing the wording of our initial blockchain vignette scenario (i.e., *with DLT* and *with P2P*) which utilized the words "new technology design" to avoid potential hype biases with an identical vignette scenario that actually utilized the term "blockchain" to determine whether there is some additional, uncaptured aspect of blockchain designs that were missed during the main study (e.g., blockchain hype) due to a participant's prior knowledge of blockchain but not the underlying technologies from which it is built. As our focus of this analysis is on the potential bias that exists in our "blockchain" scenario (i.e., *with DLT* and *with P2P*), we only focus on a single vignette from our initial study and not a complete replication of all four scenarios. Following the same procedures detailed in the main analysis, a confirmatory factor analysis of this secondary sample had the following fit statistics: $chi^2 = 393.78$, $df = 209$, $CFI = 0.94$, and $RMSEA = 0.078$, indicating an adequate measurement model fit. Table 4 provides the descriptive statistics and correlation matrix for this secondary sample. Comparing the two scenarios (both serving as our blockchain design features scenario containing *distributed ledger technologies* and *peer-to-peer network features*, one using the term "blockchain" and one using the term "new technology design"), our results indicate no difference between the manipulation checks or any of the focal constructs within our models. This analysis provides evidence that the use of the word "blockchain" in our vignettes did not significantly affect the participants' responses compared with our initial design using "new technology design" and therefore was not affected by potential biases in this study. This provides further evidence of the robustness and design of our experimental vignettes, which were designed to reduce the potential bias of prior blockchain knowledge due to media coverage and hype. The summary of our results for the hypotheses testing is presented in Table 5 with the detailed interpretation and implication of the supported and unsupported findings provided in the following section.

Table 3: Mediating effects of perceptions on willingness to use

	Point estimate	SE	BC 5,000 BOOT	
			LL95	UL95
Total effect				
Willingness to use	**.28**	**.07**	**.1494**	**.4357**
Direct effect				
Willingness to use	.07	.07	−.0558	.2106
Mediating effects				
Perceived risk	.20	.01	−.0104	.0290
Trustworthiness–competence	**.07**	**.03**	**.0208**	**.1346**
Trustworthiness–integrity	.05	.04	−.0125	.1230
Procedural justice	.01	.02	−.0357	.0669
Distributive justice	**.07**	**.03**	**.0277**	**.1502**
Interactional justice	−.01	.03	−.0595	.0518

Note.: The significant total, direct, and mediating effects (highlighted in bold) are determined by the upper and lower 95% confidence intervals from our 5,000 bootstrapped estimations not including 0, indicating an effect significantly different from 0. The significant effects are indicated in bold. Total effect estimate includes blockchain design features effect on willingness to use without the presence of mediators while the direct and mediating effects estimates include blockchain design features effect on willingness to use with the presence of mediators following Hayes (2013).

DISCUSSION

The motivation for our research was to understand how supply chain managers perceive features of blockchain technologies and how these perceptions may influence their willingness to use the technologies. Such an understanding is a precursor to designing and executing a successful implementation, as managerial support and willingness to use the technology is critical for large, organizational IT implementations. This is especially true for those as novel as blockchain technologies, which require significant partner coordination and trust (Francisco and Swanson 2018). Our findings reveal that the combination of the DLT and P2P features increase managers' perceptions of trustworthiness (competence and integrity) and perceived justice (procedural, distributive, and interactional) in the technology. Further, despite media claims and hype regarding blockchain technologies, managers do not perceive blockchain as more or less risky than other technology designs within our experimental design. These results suggest that, in general, managers have a positive attitude toward blockchain technologies and view them as providing increased trust and justice within the supply chain. However, not all of these beneficial trust and justice aspects subsequently increase a managers' willingness to use blockchain technologies above and beyond a traditional technology design, providing insights into what focal mechanisms can be leveraged when attempting to increase willingness to use.

We found that some, but not all, of these perceptions functioned as the mediators of the blockchain features' effect on managers' willingness to use the technology. We were able to identify the primary mediating constructs, trustworthiness–competence and perceived distributive justice, as the two psychological mechanisms that primarily influence the willingness to use blockchain technologies, while trustworthiness–integrity and procedural justice also function as statistically significant moderators when tested separately indicating weaker mediation. Interestingly, two components hypothesized to be important for increased willingness to use based on prior research were risk (Kull et al. 2014) and interactional justice (Narasimhan et al. 2013), which provided little support within the context of blockchain. More specifically, we find that blockchain design features have no impact on the level of risk compared with other technology designs, indicating that managers perceive blockchain technologies to be equally risky as their alternatives at this early stage of diffusion in the market. Additionally, while the results show that blockchain features do have a direct and significant impact on perceived interactional justice, it did not function as mediating mechanisms to the willingness to use in this context.

In an attempt to examine the ecological validity of our model and findings, we conducted several post hoc field interviews with supply chain and IT managers to develop a deeper understanding of why perceived risk and interactional justice do not function as significant mediators (Tangpong et al. 2010; Mir et al. 2017; Ellis et al. 2018). To this end, our interviews were conducted after our initial analyses and focused on eliciting the interviewees' understanding and usage of blockchain technologies within their organization, their experience with IT implementations in their organization and supply chain, and also their interpretation of our findings, both significant and nonsignificant.

A supplier for a large retailer commented that: "*The idea and the goal (represented by the blockchain technologies) have been out there for many years. Risk of technology is not the issue. The issue is that the supply chain partners are afraid of others using the data to go against them*." This indicates that supply chain partners do not perceive a technology, such as a blockchain technology, as riskier because they have been jointly working on achieving the goal of data decentralization and peer-to-peer networks for many years. It is the usage of the data that concerns managers. Additionally, another manager asserted: "*Blockchain is too new and too fresh; the policies and procedures are not fully developed.*" This would indicate that the interactional aspect of perceived justice may evolve with the maturity of blockchain technologies.

Theoretical implications

Our research makes the following contributions to the literature on blockchain, supply chain management, and information systems.

First, while prior research has focused on proof of concepts (e.g., Kim and Laskowski, 2018), technical explanations of blockchain (e.g., Mainelli and Smith, 2015), and context-specific case studies (e.g., Angraal et al., 2017), our research is the first empirical and comprehensive study of the willingness to use blockchain technologies in the supply chain field. We captured supply chain and IT managers' perceptions of this emergent technology by presenting a scenario of blockchain technologies in their organization. We first inventoried psychological constructs (risk, trustworthiness, and justice) that have been used as a lens in prior research to understand B2B supply chain relationships and behavior with respect to interactions with human supply chain agents. We then investigated how these constructs may function in the context of blockchain technologies and influence the willingness to use the technology, as managers view it as an embedded software agent that provides fair justice and trustworthy interactions.

Second, our research contributes to the supply chain technology literature by using design theory to examine how blockchain's core design features influence perceptions of the technology and subsequent willingness to use. In this research, two key structural blockchain design features (DLT and P2P) are described and their potential impacts are examined within the supply chain context. Design theory emphasizes explaining how the design and features of a technological innovation affect its adoption and sustained use (Tanskanen et al. 2015). Our results show that the unique combination of DLT and P2P features through blockchain technologies had the greatest positive effect on willingness to use over other technology designs. This indicates that the distinct components of blockchain technology (DLT and P2P), despite being used separately in technology for decades, are perceived by managers to be unique and provide additional functionality when combined, above and beyond their individual components.

Third, this research introduces the notion of the embedded *software agent*. This notion puts forward the uniqueness of emerging technologies, such as blockchain technologies, that may have a significant influence on supply chain relationships. A software agent is conceptualized as combining the capabilities of different systems (e.g., decision support, expert systems, recommendation systems), resulting in creative applications that can act and perform actions in an unbiased manner across all participants in the network (Nissen and Sengupta 2006). We argue that a solid understanding of the potential impact of blockchain as a software agent is vital. Blockchain technologies function as

Table 4: Descriptive statistics and correlation matrix for Robustness Sample

Variables	Mean	SD	AVE	TC	TI	PJ	DJ	IJ	Risk	Will.	PU	PI	PK	Age	GND	Co.	Pos.
Trusting beliefs–competence (TC)	5.66	0.99	0.76	**0.87**													
Trusting beliefs–integrity (TI)	5.75	0.89	0.65	.488**	**0.81**												
Justice–procedural (PJ)	5.97	0.96	0.85	.417**	.499**	**0.92**											
Justice–distributive (DJ)	5.50	0.97	0.78	.519**	.456**	.384**	**0.88**										
Justice–interactional (IJ)	6.11	0.89	0.78	.531**	.429**	.553**	.449**	**0.88**									
Risk	3.74	1.58	0.85	−.292**	−.278**	−.268**	−.237**	−.366**	**0.92**								
Willingness (Will.)	5.40	1.20	0.80	.682**	.464**	.302**	.533**	.461**	−.408**	**0.89**							
Perceived usefulness (PU)	5.37	0.95	0.82	.522**	.432**	.334**	.514**	.413**	−.303**	.517**	**0.91**						
Personal innovativeness (PI)	5.12	1.11	0.84	0.08	0.10	0.07	0.12	0.11	−0.01	0.13	.196*	**0.92**					
Previous knowledge (PK)	3.43	1.45	0.73	0.10	0.03	0.06	0.09	−0.02	0.02	0.09	.368**	0.06	**0.85**				
Age	40.87	12.34		0.07	−0.12	−0.12	0.02	−0.04	0.05	−0.03	−0.04	−0.15	0.02	**N/A**			
Gender (GND)	0.58	0.50		0.13	0.12	−0.01	0.09	0.01	0.09	0.19	0.09	.368**	0.06	0.09	**N/A**		
Year in current company (Co.)	4.04	1.90		0.13	.193*	0.05	0.11	−0.03	−.211*	0.10	−0.06	−0.18	.245*	0.46**	−0.01	**N/A**	
Year in current position (Pos.)	2.28	1.07		0.12	0.05	−0.04	0.05	0.00	−0.08	0.10	0.03	−0.13	−0.08	0.48**	.269**	.277**	**N/A**

Note.: Square root of AVE on the diagonal; female coded as 0; male coded as 1
$n = 69$.
*$p < .05$;
**$p < .01$.

embedded software agents and act as trust generators by replacing traditional supply chain intermediaries (The Economist 2015). Although frequently called "the trust machine," our research is the first to empirically and comprehensively study managers' perceptions of blockchain as a trustworthy technology. We find that, of the mediating mechanisms examined, trustworthiness in the competence and the distributed justice of the technology fully mediated the effects of the blockchain design features on willingness to use, indicating their importance in helping influence managers to use the technology. Further, we found from our robustness tests that both trustworthiness–integrity and procedural justice served as weak mediators of the blockchain design features. These findings indicate that managers perceive the blockchain technology as an embedded software agent that provides significantly increased trust over traditional technology designs and implements fair justice through consistent procedures and distribution of outcomes.

Additionally, our research adds to the classical information systems' literature on the diffusion of emergent technologies within supply chains. According to the classic diffusion process (Williams and Tao 1998; Russell and Hoag 2004), social factors such as managers' perceptions (affective stage) function as mediators of the blockchain effect (cognitive stage) on managers' decision-making process (behavior stage). Specifically, our results reveal that when introduced to different combinations of blockchain features (only DLT, only P2P, the combination of them, or neither of these two features), managers develop different perceptions of risk, trustworthiness, and justice. The perceived trustworthiness of blockchain's competence and its distributive justice are found to be the primary mechanisms driving managers' willingness to use blockchain technologies.

However, we also find that some mechanisms, such as the risk of the technology, had no impact within our model. While blockchain technologies have been touted in the popular press as being less risky than traditional technologies in regard to the immutability and transparency of the data, our results and post hoc interviews indicate that the increased sharing and transparency of the data itself provides additional levels of risk and concerns for managers over existing interorganizational technologies. Further, at the supply chain level, the implementation of a large, novel technology is a risky endeavor, regardless if it is a blockchain technology, and managers understand that risks will come with any technology. While the blockchain technologies may increase trust in the history of the data and provenance, it also introduces new risk factors, such as increased visibility by competitors, or power differences between small and large firms.

Managerial implications

Our research also has significant managerial implications. First, our research and findings are forward-looking, which prepare supply chain partners in encouraging the usage of blockchain technologies. Both our research and findings underline the technological knowledge and the employees' perceptions of using blockchain technologies in supply chain. Specifically, we provide solid yet understandable explanations of what blockchain is by providing the definitions of its key features. Blockchain technology enables authenticated transactions across a network of supply chain participants, and as such, the implementation process

Table 5: Results of hypotheses tests

	Hypotheses	Supported?
Risk	$\mathbf{H_1}$: Blockchain design features have a direct negative effect on managers' risk perceptions.	No
Trustworthiness	$\mathbf{H_{2a}}$: Blockchain design features have a direct positive effect on managers' trustworthiness–competence.	Yes
	$\mathbf{H_{2b}}$: Blockchain design features have a direct positive effect on managers' trustworthiness–integrity.	Yes
Justice	$\mathbf{H_{3a}}$: Blockchain design features have a direct positive effect on managers' perceptions of procedural justice.	Yes
	$\mathbf{H_{3b}}$: Blockchain design features have a direct positive effect on managers' perceptions of distributive justice.	Yes
	$\mathbf{H_{3c}}$: Blockchain design features have a direct positive effect on managers' perceptions of interactional justice.	Yes
Perceptions as mediators	$\mathbf{H_4}$: Risk negatively mediates the effect of blockchain technology on managers' willingness to use.	No
	$\mathbf{H_{5a}}$: Trustworthiness–competence positively mediates the effect of blockchain technology on managers' willingness to use.	Yes
	$\mathbf{H_{5b}}$: Trustworthiness–integrity positively mediates the effect of blockchain technology on managers' willingness to use.	No
	$\mathbf{H_{6a}}$: Procedural justice positively mediates for the effect of blockchain technology on managers' willingness to use.	No
	$\mathbf{H_{6b}}$: Distributive justice positively mediates for the effect of blockchain technology on managers' willingness to use.	Yes
	$\mathbf{H_{6c}}$: Interactional justice positively mediates for the effect of blockchain technology on managers' willingness to use.	No

naturally includes the complete supply chain and is much more complex than internally focused organizational technology adoptions. While extant blockchain research primarily focuses on explaining what blockchain technology is, how it functions, and its proposed benefits (Gramoli 2017; Aste et al. 2017; Novo 2018), little is known about what specific features of blockchain technologies are the actual drivers of supply chain managers' willingness to adopt and use this technology due to the early adoption stages of blockchain across industries. Our research emphasizes the DLT and P2P—two key features of blockchain technologies that differentiate with other technologies—and their influence on supply chain managers' willingness to use the technology.

Besides a deep understanding of what blockchain technology is, we argue the next big hurdle in the diffusion of blockchain technologies is managers' willingness to use blockchain as organizations and supply chains being to integrate this technology into their processes. Therefore, our second managerial contribution is providing empirical evidence that adds to the knowledge base on blockchain acceptance among supply chain partners. The proposed informational and transactional benefits of blockchain are only fully realized when all participants in the supply chain are utilizing the system to create a single record of the truth (Iansiti and Lakhani 2017). Successful implementation and performance of blockchain technologies within the supply chain require significant collaboration and adoption across supply chain partners to define the usage, behaviors, and governance of the system, as well as working collectively to onboard the entire supply chain network onto the system. Currently, many large firms are pilot testing blockchain with their key partners with intentions to expand to more participants and levels of the supply chain. However, there are two respects in which eventual adoption and use may be an issue for new technology designs. Employees who are accustomed to legacy systems and processes have been shown to be reluctant to adopt and use new systems that may be introduced to improve business processes (Murfield et al. 2016; Hardgrave and Patton, 2016). Furthermore, supply chain partners (e.g., small/medium businesses, government agencies) in the supply chain are potential blind spots in the development phase due to differences in technology abilities and experience. Previous emergent data technologies in the supply chain, such as EDI and RFID, found that small and medium suppliers' companies have limited capability and resources to adopt such radical technologies and to manage their process change. The internal and external complexities associated with a firm attempting to implement a new technology are an unavoidable issue. Understanding managers' willingness to use blockchain technologies is critical to facilitating a successful implementation.

Third, to better understand the changes that blockchain would bring to supply chains by the removal of traditional third parties and replacement with automated blockchain technologies, we utilized the concept of an embedded software agent from the information system literature (Nissen and Sengupta 2006). Managers should be aware that blockchains may eventually function as the unbiased software agent once successfully integrated into the interactional processes, as it can autonomously standardize, monitor, and coordinate all the data and processes in the supply chains that traditional third parties and mediators may have served. Users of blockchain technologies will have to shift from trusting in a human behind the screen making decisions to trusting the algorithm and processes that are embedded into the blockchain technology. Helping organizations find the best language and approach that will describe the features of the new technology in such nontechnical terms is likely to be necessary to help educate and encourage supply chain partners to support the use of blockchain technologies over more traditional technologies.

Fourth, our results indicate that the success of a large, interorganizational technology implementation may depend on the complexities of the communications process in sharing the features, benefits, and outcomes of using a specific technology, focusing on effective communication and the education of key design features of blockchain technology while reducing the potential bias of media hype in the market will facilitate the first step of a successful implementation. Our results indicate that to enhance such communications, managers need to understand the impacts that blockchain design features have on the trustworthiness and justice that an embedded software agent can provide over traditional technology designs. More specifically, an understanding of which mediating mechanisms that have been shown to be important in traditional B2B interactions (e.g., risk, trust, justice) is applicable in a blockchain context and which should be leveraged as talking points to encourage future use.

Our research presented the concept of blockchain technologies to nontechnical professionals through the discussion of its core features instead of pushing the *term* blockchain, which may present biased perceptions due to the media coverage and hype around specific instances of blockchain implementations such as cryptocurrencies. While the introduction of blockchain technologies was realized through cryptocurrencies such as Bitcoin, which has had both a positive and negative reception in the market, the use of blockchain technologies does not require the use of cryptocurrencies, and therefore, focusing on the underlying technologies instead of examples of existing blockchain applications may provide a less biased approach to influencing willingness to use the technology. To this end, we introduced the notion of a software agent and two underlying features that, when combined, create blockchain technologies (DLT and P2P) and subsequently provide examples of how these features can lead to operational improvements (higher efficiency, consistency, and reachability) across supply chains. The discussion of these operational improvements at a feature level and the mechanisms through which they impact managers and supply chain agents—instead of through the term blockchain, with its associated media bias—may provide a more effective method for encouraging willingness to use.

Limitations

There are some limitations in our research that should be recognized. One is that the findings are blockchain-specific. Blockchain is a very unique technology in that it has the combined features of DLT and P2P. Although we focused on these two key features, from a technical perspective, blockchain might have other key features as the technologies evolve, such as various cryptographic algorithms and consensus mechanisms that are important for different organizational roles. The outcome of cryptographic algorithms and consensus is the verifiable, immutable data which are stored by the DLT. We did not include these as separate features in this research, but instead focused on the outcomes of *using* blockchain technology as opposed to *how* blockchain works, which most individuals in the current environment do not understand, as indicated by our low levels of blockchain knowledge across participants. End users, who are the focus of our research, do not need to understand how a technology works, but do need to understand what it can accomplish. While changes in the consensus and cryptography mechanisms impact the potential speed, rules, and security of the network, they encompass the *how* components of blockchain technologies, which will continue to evolve quickly compared with the *what* components of DLT and P2P, which will remain a key design feature as blockchain technologies evolve.

Extant information system literature has investigated drivers of individuals' adoption behavior (Venkatesh and Davis 2000; Rai et al. 2002; Venkatesh et al. 2007). For example, perceived usefulness and perceived ease of use are commonly used in models of adoption (e.g., Davis 1989). We did not use the established adoption models (beyond using perceived usefulness as a control variable) because those models are suitable for users who already have some knowledge of and experience with the new technology, which most organizations and employees have not yet implemented in the current environment. Additionally, our research did not include the issue of cost which is a typical concern to new technologies because we do not anticipate significant differences in managers' perceived costs across scenarios. However, we suggest that future research should apply the adoption models with the cost element to study blockchain technologies as the blockchain ecosystem continues to evolve and managers gain some hands-on experience.

In addition, there are still many uncertainties about blockchain technology. Even if business partners are willing to utilize it, blockchain should be used with caution and adjusted according to the business context. Moreover, there are other factors affecting suppliers' willingness to use blockchain technologies, such as the existing status and length of the relationship, the types of industry, and the size of the company. A behavioral experiment, however, provides a direct and solid understanding of the blockchain design features and their direct and indirect effects on managers' perceptions and willingness to use. Based on this initial work, there is scope for future studies in the field to examine the influence of environmental and organizational issues on implementation.

CONCLUSION

Our research was motivated by a desire to understand how supply chain agents may perceive blockchain technology and the effect on their willingness to use the technology. The results provide insights into how to facilitate a successful interorganizational blockchain implementation process by identifying critical drivers of future adoption. Given that blockchain technologies are unlikely to be useful if supply chain agents do not use them, we posit that understanding supply chain agents' perceptions of the technology is a necessary precursor to successful interorganizational implementation.

As noted in the previous section, the findings in this research provide evidence that blockchain design features do indeed affect managers' willingness to use blockchain technologies. Their perceptions of risk, trustworthiness, and justice also increase in the face of blockchain features. Prior research used these constructs in the context of human partners. However, the findings further suggest that supply chain partners may see blockchain technologies as an embedded reliable and unbiased software agent that plays an increasingly important role in interorganizational transactions. Our research is forward-looking and can be interpreted as a call to anticipate the diffusion process and the importance of the role an embedded software agent may play in the diffusion of this novel technology.

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APPENDIX 1

STIMULUS MATERIAL

Scenario introduction

Imagine that you are a supply chain manager from a manufacturing company. Recently, your customer—a retailer—suggested that your company should use a new technology design that news media and big companies are discussing and testing, and so is this retailer. Knowing little about this technology design, you decide to do some research before you make a decision whether or not to approach your boss with the idea.

Vignette 1: Blockchain design features (W DLT, W P2P)

You found a review from *The Harvard Business Review* which highlighted the following main features of the technology design:

- Verifiable records: Each party has access to the entire database and its complete history so that each party can verify the records of its transaction partners directly, without an intermediary. This guarantees that each party has access to a fully transparent historical record of transactions.
- Permanent records: The technology design does not allow data to be changed or deleted once it has been uploaded.
- Real-time data transmission: Communication occurs directly between peers, and all information is stored and forwarded to all other peers. Therefore, information transmission is direct and in real time, reaching trading partners instantaneously.
- Synchronized communication: Trading partners using this technology design are in constant communication and receipt of information is synchronized *(All things considered, how would you evaluate this new technology? Anchors: Strongly disagree to Strongly agree).*

Vignette 2: W DLT, WO P2P

You found a review from *The Harvard Business Review* which highlighted the following main features of the technology design:

- Verifiable records: Each party has access to the entire database and its complete history so that each party can verify the records of its transaction partners directly, without an intermediary. This guarantees that each party has access to a fully transparent historical record of transactions.
- Permanent records: The technology design does not allow data to be changed or deleted once it has been uploaded.
- Delayed data transmission: Communication occurs through a central hub and information is forwarded to other peers on request. Therefore, information transmission is indirect and not in real time, reaching trading partners when they make a manual request.
- Asynchronized communication: Trading partners using this technology are not in constant communication and receipt of information is asynchronous.

Vignette 3: WO DLT, W P2P

You found a review from *The Harvard Business Review* which highlighted the following main features of the technology design:

- Real-time data transmission: Communication occurs directly between peers and all information is stored and forwarded to all other peers. Therefore, information transmission is direct and in real time, reaching trading partners instantaneously.
- Synchronized communication: Trading partners using this technology design are in constant communication and receipt of information is synchronized.
- Unverifiable records: Each party has access to their portion of the database and its complete history. Each party can verify the records of its transaction partners by communicating with that party. Because of the private record keeping, each party

Figure A1: Blockchain design features effect on willingness to use.Mean values of willingness to use are plotted for each scenario; w = with, wo = without; DLT = distributed ledger technologies, P2P = peer-to-peer network.

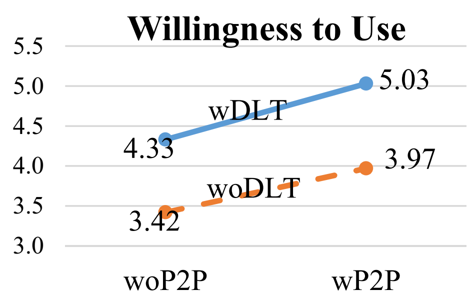
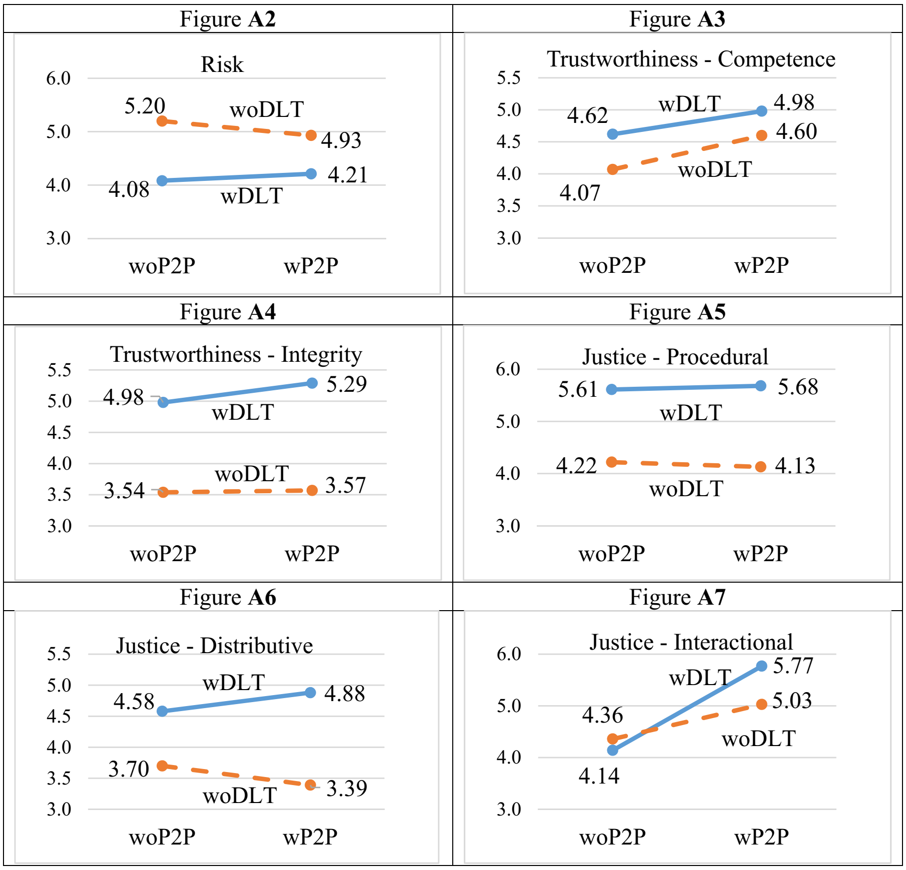


Figure A2-7: Blockchain design features on managers' perceptionsMean values of willingness to use are plotted for each scenario; w = with, wo = without; DLT = distributed ledger technologies, P2P = peer-to-peer network.



does not necessarily have a guarantee of a fully transparent historical record.

- Impermanent records: The technology design allows data to be changed or deleted once it has been uploaded.

Vignette 4: WO DLT, WO P2P

You found a review from *The Harvard Business Review* which highlighted the following main features of the technology design:

- Unverifiable records: Each party has access to their portion of the database and its complete history. Each party can verify the records of its transaction partners by communicating with that party. Because of the private record keeping, each party does not necessarily have a guarantee of a fully transparent historical record.
- Impermanent records: The technology design allows data to be changed or deleted once it has been uploaded.
- Delayed data transmission: Communication occurs through a central hub and information is forwarded to other peers on request. Therefore, information transmission is indirect and not in real time, reaching trading partners when they make a manual request.
- Asynchronized communication: Trading partners using this technology are not in constant communication and receipt of information is asynchronous.

Manipulation checks

Based on the scenario you just read, this new technology design contains the following features.

7-point Likert scales (1 = strongly disagree; 7 = strongly agree):

- Verifiable records
- Permanent records
- Real-time data transmission
- Synchronized communication

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