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The Struggle is Real: Insights from a Supply Chain Blockchain Case

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Despite the anticipated benefits and the numerous announcements of pilot cases, we have seen very few successful implementations of blockchain technology (BCT) solutions in supply chains. Little is empirically known about the obstacles to blockchain adoption, particularly in a supply chain's interorganizational setting. In supply chains, blockchains' benefits, for example, BCT-based tracking and tracing, are dependent on a critical mass of supply chain actors adopting the technology. While previous research has mainly been conceptual and has lacked both theory and empirical data, we propose a theory-based model for interorganizational adoption of BCT. We use the proposed model to analyze a unique in-depth revelatory case study. Our case study confirms previous conceptual work and reveals a paradox as well as several tensions between drivers for and against (positive and negative determining factors, respectively) of BCT adoption that must be managed in an interorganizational setting. In this vertical context, the adoption and integration decision of one supply chain actor recursively affects the adoption and integration decisions of the other supply chain actors. This paper contributes midrange theory on BCT in supply chain management (SCM), future research directions, and managerial insights on BCT adoption in supply chains.

Keywords: Blockchain technology; Case study research; Interorganization systems; Provenance; Supply chain transparency; Technology adoption

INTRODUCTION

Few information systems are currently gaining as much attention as the ones building on blockchain technology (BCT; Panetta 2018; Babich and Hilary 2019). BCT has generated trust in cryptocurrencies, such as Bitcoin and Ethereum, by ensuring the authenticity of digital resources and identities. Therefore, the technology is often referred to as a "trust machine" (e.g., Beck et al. 2016; Clemons et al. 2017). Beyond cryptocurrencies, several BCT initiatives (e.g., Provenance.org; Wheeler 2017) are riding on the trend of the increasing pressure on retailers, for example, to increase transparency and disclose supply chain information (Marshall et al. 2016; Saberi et al. 2019). Moreover, shippers and logistics service providers such as Maersk, Nestlé, and Walmart are declaring BCT will greatly change and improve supply chain management (SCM; Doe 2017).

However, change and improvement in supply chains only come with the adoption of such technology across the involved parties and value chain partners. When the state of BCT in SCM was examined at the time of this writing, only a few BCT projects had been adopted on a larger scale. IBM's TradeLens and Food Trust are rare examples of BCT-enabled solutions in supply chains that have moved beyond a pilot state. However, this scarcity of BCT projects does not mean that the interest in this new technology has decreased (Panetta 2018; Budman et al. 2019) but shippers and their logistics service providers seem to struggle (Higginson et al. 2019) because cases of scalable adoptions in their supply chains are rare (Budman et al. 2019). At the same time, several academic conferences have hosted BCT in supply chain tracks, several journals have announced forthcoming special issues on BCT applications (e.g., Rao et al. 2017; Koh et al. 2018), and the first scientific papers about BCT in SCM have been published in academic journals (Babich and Hilary 2019; Roeck et al. 2019; Wang et al. 2019).

While existing papers have merit in increasing the understanding of BCT and conceptually explaining BCT in operations and SCM, they have two limitations. First, they are mainly conceptual (Wüst and Gervais 2017; Treiblmaier 2018; Babich and Hilary 2019; Schmidt and Wagner 2019). Second, no papers have been theory-based nor have any addressed the critical question of BCT adoption in interorganizational supply chain settings. Extant contributions are limited to general explorations of BCT's benefits and obstacles (e.g., Wang et al. 2019). However, without any empirical evidence or theory, studying BCT adoption conceptually renders neither a full understanding of the adoption phenomenon in the complex setting of interorganizational supply chains nor the benefit from previous knowledge accumulated in the theory. To contribute to theory and practice, theoretical and empirical grounding is necessary when studying BCT adoption in supply chains.

Information systems (IS) research deals with technology adoption spanning organizational boundaries, that is, interorganizational system (IOS; Premkumar et al. 1997). In the case of BCT in supply chains, the value of a single organization's adopting BCT is at best limited because the benefits are reaped when a critical mass of stakeholders and value chain partners adopt the technology. In other words, BCT entails *network effects* (Katz and Shapiro 1994) because they are only achieved when the number of members in a network adopting a technology is at or above the threshold at which the technology yields benefits.

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BCT-enabled transparency in supply chains is an example of such a network effect as multiple members and value chain partners share information through a distributed ledger. As indicated by the significant attention practitioners and scholars pay to this issue, understanding the specific characteristics of BCT adoption in supply chains is important, especially when considering the BCT's large anticipated impact on supply chains (Casey and Wong 2017; Blossey et al. 2019). Despite the impact and promised benefits, the adoption is described as having "lack of progress" (Higginson et al. 2019). Therefore, we aim to conceptualize BCT adoption in supply chains and contribute to SCM theory by asking the following research question:

Why do supply chains, despite the promising benefits, struggle to adopt BCT?

In answering this question, we elaborate on IOS adoption theory (Iacovou et al. 1995; Premkumar et al. 1997) while aiming to address the lack of empirically and theoretically grounded work on BCT adoption in supply chains. We investigate the applicability of IOS adoption theory to our aim by using this theory to frame our results from a BCT pilot study. The focus is on BCT-enabled vertical supply chain transparency in an IOS context. Supply chain finance, trade platforms, and other horizontal or diagonal applications of BCT are outside this paper's scope.

Because the technology is still in an early stage and an ex ante evaluation is difficult, we cannot comprehensively elaborate on BCT. However, our study offers two main midrange theoretical contributions (Stank et al. 2017). Through in-depth case study, we complement previous conceptual or expert-based studies by identifying and conceptualizing trade-offs (tensions) going beyond previous literature (Babich and Hilary 2019; Wang et al. 2019) as well as paving the way for future design research to address the issues that currently prevent large-scale adoption. This study also proposes a model, based on IOS theory, to determine adoption of BCT in supply chains.

THEORETICAL BACKGROUND

To theorize on innovation or technology adoption in supply chains, SCM scholars often draw from IS research (Autry et al. 2010; Hazen et al. 2012), which has a long history of studying interorganizational adoption of technical innovations (Barrett and Konsynski 1982; Grover 1993). Innovation diffusion is typically divided into three stages: (1) initiation (awareness), (2) adoption (the decision to implement), and (3) routinization (actual use) (Zhu et al. 2006). The focus of most IS—as well as SCM—research is on the second stage, the adoption (Hazen et al. 2012).

A subset of the IS literature focuses on IOS adoption. According to Johnston and Vitale (1988), "an IOS is built around information technology, i.e., around computer and communications technology, that facilitates the creation, storage, transformation, and transmission of information. An IOS differs from an internal distributed information system by allowing information to be sent across organizational boundaries. Access to stored data and applications programs is shared, sometimes to varying degrees, by the participants in an IOS" (p. 154). Thus, BCT is an IOS, and the application of IOS adoption theory to BCT adoption in supply chains is warranted.

Adoption of interorganizational information systems

IOS adoption differs from general technology adoption in that the decision to adopt is made by the focal firm considering not only its own business but also the adoption decisions of other actors in the supply chain. Researchers have used technologies such as electronic data interchange (EDI), barcodes, and RFID when developing and testing IOS adoption theories. Several factors influence technology adoption, and a large part of the research is midrange theory, that is, contextualized based on a specific technology, a single industry, or a distinct organizational setting (Grover 1993; Venkatesh et al. 2003). While studying a single organization's adoption of an innovation is complex, studying and anticipating future adoption of IOS in interorganizational settings are even more complex due to numerous environmental and firm-specific factors (Riggins and Mukhopadhyay 1994).

Several models exploring IOS adoption have been tested with mixed results (cf., Grover 1993; Autry et al. 2010). Although numerous factors have been found to influence technology adoption (Venkatesh et al. 2003), most studies determine that the following three factors are significantly and consistently related to interorganizational adoption: (1) relative advantage, (2) complexity, and (3) compatibility (Iacovou et al. 1995; Premkumar et al. 1997).

Blockchain characteristics and supply chain application

In contrast to traditional centralized databases, BCT distributes the ledger of transaction data in a network of multiple members. Consequently, BCT is part of the distributed ledger technology (DLT). The transaction data are stored in blocks that are chronologically chained together, thus the name *blockchain* (Swan 2015). Within such a network, every member (represented as a node) stores the entire blockchain (BC) and, therefore, has all the transaction data ever stored in the BC. Thus, all nodes possess the same data, and manipulation of the historical transaction's data is detected by automatically comparing the ledger within the network (Beck et al. 2017). To enter new transaction data (i.e., adding a block with transaction data to the existing BC), a consensus among the network's nodes is needed. Once this consensus is reached, the new block is distributed through peer-to-peer communication to all members in the network. Consequently, all members have the same record of transactions. Unlike in centralized database systems, this peer-to-peer communication and the distributed ledger eliminate the technical need for a trusted central party to coordinate and communicate these changes (Beck et al. 2016). There are two main types of blockchains (Wüst and Gervais 2017):

- *Public blockchains*: With this type, every transaction is public (and, thus, "permissionless"), and users can remain anonymous. The network typically has an incentivizing mechanism to encourage more participants to join the network.
- *Permissioned blockchains*: With this type, participants must receive an invitation or otherwise have permission to join. Access tends to be controlled by a consortium of members (consortium blockchains) or by a single organization (private blockchains).

Scholars have started conceptualizing the technology's benefits in supply chains. In the operations management context, Babich and Hilary (2019) identify visibility, aggregation, validation, automation, and resiliency as BCT's main promised benefits. Saberi et al. (2019) see transparency, trust, automation, security, and decentralization as BCT's key benefits in SCM. Blossey et al. (2019) identify transparency, automation, and validation as the technology's benefits, while Kolb et al. (2018) add immutability and high accessibility to the long list of perceived benefits. In the supply chain context, the interviews by Wang et al. (2019) suggest these benefits:

- *BCT improves supply chain transparency.* Allowing the development of services such as track and trace, BCT reduces the need for double-checking because data validation is automated. Furthermore, BCT allows tracing transactions, thus providing a proof of provenance.
- *BCT ensures secure information sharing and builds trust.* The information (one data pool) within blockchains is viewable by all participants and cannot be altered by a single entity, thus creating trust and reducing fraud. Users can remain anonymous or provide proof of their identity.
- *BCT allows for operational improvements.* It speeds end-to-end supply chain execution and allows for increased volume as well as data accuracy. BCT-enabled solutions distribute data within seconds throughout the entire network. The consensus mechanisms validate the data integrity and build an integer basis for smart contracts, enabling automation along the supply chain.

As previously noted, the promised benefits arise from a network—that is, the benefits only occur if multiple supply chain actors adopt the technology (cf., Sternberg and Andersson 2014), something previous studies of blockchains in SCM and OM have not addressed. In terms of a network effect (Katz and Shapiro 1994), other supply chain actors' decision to apply and use the technology affects the possible added value for all the participating and using members. Improved supply chain transparency, secure information sharing, and operational improvements cannot be achieved solely by individual technology adoption. According to Shapiro and Varian (1998), each actor who adopts and uses a certain product or service (e.g., a BCT-enabled supply chain transparency solution) increases the value of that product or service. Such a supply chain-wide BCT adoption on an interorganizational level is necessary for achieving gapless visibility and for disclosing a product's journey along the supply chain.

Besides considering BCT's many promised benefits and other supply chain actors' decisions to adopt and integrate the technology, the SCM and operations management literature points to the importance of considering the obstacles to BCT adoption (Babich and Hilary 2019; Schmidt and Wagner 2019). For example, Babich and Hilary (2019) discuss five weaknesses: (1) the lack of privacy, 2) the lack of standardization, (3) the "garbage in, garbage out" (GIGO) problem, (4) the black box effect (i.e., the need for consumers to trust the implementation), and (5) inefficiency.

Based on Wang et al. (2019), the following possible obstacles of BCT adoption and usage in SCM (with sample issues) are identified:

- *Culture:* Changing operational protocols is a hurdle. Conflicting stakeholder objectives and cultural hurdles to overcome with innovations might interfere with a successful adoption along the supply chain.
- *Necessity and confidence*: Many organizations are unsure of BCT functions and benefits. Thus, they decline the adoption in their organization.
- *Information sharing*: Ensuring input data's integrity is difficult and requires much effort. These factors can discourage organizations from adopting BCT in their supply chains.
- *Technological*: Adopting BCT poses the inherent risk of overcomplicating the supply chain's ecosystems. Moreover, the lack of standards hampers BCT's adoption along the supply chain.
- *Cost, regulation, and privacy*: Involved organizations' resistance to a high level of transparency and regulatory uncertainties are opponents of BCT adoption in supply chains.

It should be noted that several recent studies (e.g., Babich and Hilary 2019; Schmidt and Wagner 2019; Wang et al. 2019) are at a general level. They provide valuable theoretical implications, though neither address BCT's adoption in the supply chain context nor are they based on empirical evidence from BCT projects. Thus, given the complexity of the BCT phenomenon in the supply chain context, in-depth research is warranted that accounts for the technology as well as the intrafirm and interorganizational factors of supply chain adoption. This complexity calls for including the interdependency of obstacles and benefits on a detailed level. For example, the obstacle *information sharing* is apparently related to the benefits *BCT ensures secure information sharing and builds trust*. To fully understand the adoption of BCT in supply chains, these benefits and obstacles cannot be listed without their interrelationships.

Synthesized model

Using the IOS adoption model proposed by Iacovou et al. (1995), we explore the struggle with adopting BCT in supply chains based on real-life case study data. Thus, we go beyond the existing literature's generic listing of benefits and obstacles. Including economic, organizational, and environmental determining factors for IOS adoptions, this model was chosen for three main reasons. First, its key determining factors—*perceived benefits, organizational readiness, and external pressure*—have stood the test of time. Numerous other studies have been framed using similar factors (e.g., Chwelos et al. 2001; Zhu et al. 2003). Second, this model consists of an outside-in dimension (external pressure), enabling us to emphasize the different power levels and potential influences of the supply chain actors involved (Premkumar et al. 1997; Cox 2004). Third, in contextualizing IOS adoption, by considering BCT's benefits and obstacles in supply chains (Wüst and Gervais 2017; Babich and Hilary 2019; Wang et al. 2019), it becomes apparent that not only positive IOS factors of adoption (factors that make an adoption decision more likely, henceforth denoted as *positive IOS factors*) but also negative IOS factors of adoption (factors that make an adoption decision less likely, henceforth denoted as *negative IOS factors*) must be accounted for. Although Iacovou et al.'s (1995) model primarily addresses positive IOS factors, it is also useful for incorporating technology adoption's perceived negative effects, that is, negative IOS factors.

As previously outlined, the anticipated benefits of BCT in supply chains arise from its interorganizational use (network effects). For instance, full transparency (e.g., in terms of provenance or tracking and tracing) is only achieved when all supply chain actors adopt and contribute their data, requiring multiple partners in the supply chain to adopt in order to leverage the network effect.

This requirement is important to consider because other IOS, such as EDI, can be highly beneficial at an intrafirm level or in a dyad between only two firms. Therefore, factors determining adoption, promised benefits, and potential challenges on an interorganizational level both positively and negatively affect BCT's adoption in supply chains. As a result, trade-offs between positive and negative IOS factors must be considered when exploring the reasons supply chains struggle to adopt BCT.

Synthesizing technology adoption's determining factors (by considering both the anticipated benefits and the potential challenges of BCT in supply chains), we propose the following conceptual frame:

- On the positive side, *perceived benefits* include awareness of the focal organization's direct and indirect savings. Direct savings include reduced transaction costs, reduced inventory levels, and improved information quality in supply chain. Indirect benefits (opportunities) include increased operational efficiency, improved customer service, improved trading partner relationships, and increased ability to compete. Perceived benefits include factors related to supply chain operations. On the negative side, *perceived obstacles* to technology adoptions in supply chains are always accompanied by implementation costs. These perceived obstacles may include inefficiencies (e.g., necessary process adjustments or additional handlings to operate the technology).
- *External pressure* (in the positive sense) to adopt comes from the organizational environment in the form of promises and threats from two main categories: (1) competitors, and (2) trading partners. Firms that encounter pressure from the competition or that are exposed to environmental uncertainty adopt novel technologies in their supply chains more frequently than those that do not encounter such pressure or uncertainties. Likewise, *external resistance* to adoption—a negative IOS factor—among supply chain partners defers adoption. Reasons for resistance might be the unwillingness to implement the technology in partners' respective supply chain operations or the lack of top management support.
- *Organizational readiness*—in its positive sense—is defined as "the availability of the needed organizational resources for adoption" (Iacovou et al. 1995, p. 467). Financial resources and technological readiness as well as other resources are included. Firms with higher organizational and information communication technology readiness are more likely to adopt novel technology in the supply chain than firms with low readiness levels. Targeted forms of support (e.g., management support or technology and financial assistance) are positively associated with an organization's intention to adopt technology in the supply chain. Organizational readiness mainly indicates strategic readiness (or the lack thereof) for IOS adoption. In contrast, *organizational immaturity* represents the unavailability of required resources for adopting technology in the supply chain.

We apply the suggested positive IOS factors' perceived benefits, organizational readiness, and external pressure together with the corresponding negative IOS factors to the supply chain actors' individual firm. The relations among positive and negative IOS factors lead to trade-offs and tensions:

- *Trade-offs:* The individual decision of whether to adopt and integrate the technology is based on evaluating the trade-off between the positive and negative IOS factors. However, because BCT is an IOS, each decision affects other supply chain actors' perceptions of BCT's pros and cons and, thus, recursively the decision of whether to adopt.
- *Tensions:* Specifically, such trade-offs that cannot be properly resolved (e.g., positive arguments cannot fully rebut negative circumstances) lead to tensions. Such tensions as arguments and counterarguments can exist either within or among supply chain actors (because the positive and negative IOS factors are ex ante perceptions) and can vary among managers or functions within a firm.

Figure 1 summarizes the synthesized model of interorganizational BCT adoption in supply chains as our conceptual framework. The logic for using the model is that BCT's promised benefits and possible obstacles in supply chains foster the consideration of both positive and negative IOS factors. One supply chain actor's decision to adopt and integrate is not made in a vacuum; decisions recursively affect both the positive and the negative IOS factors of other supply chain actors.

After describing the research design and the BCT pilot study, ReLog, we apply this theoretical model to analyze and reveal why supply chains struggle to adopt BCT.

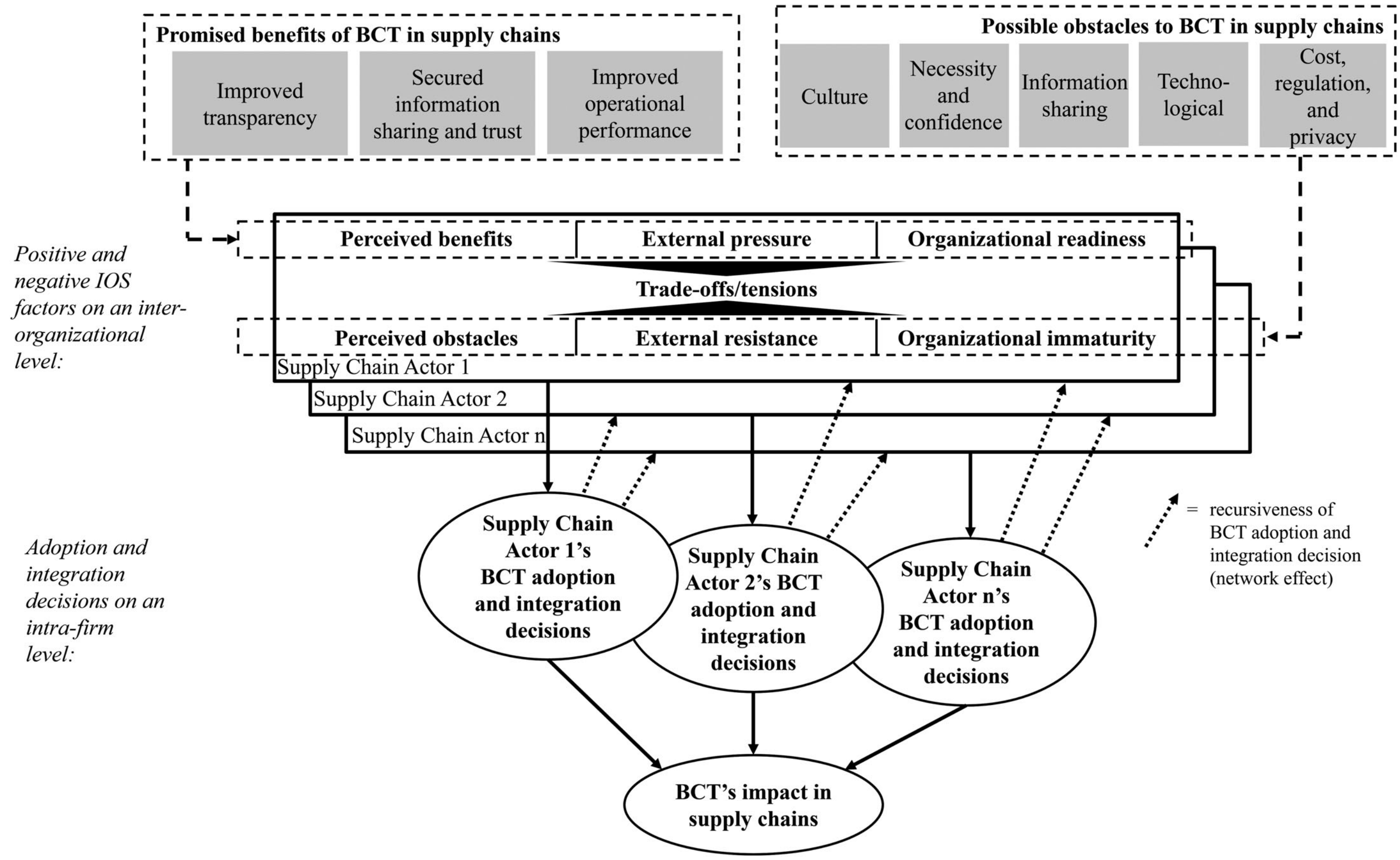
RESEARCH DESIGN

This paper's purpose and research question aim to contribute to the theory by both conceptualizing and elaborating on BCT adoption in SCM. As outlined in the background and despite "the buzz," there is a scarcity of actual blockchain adoptions in SC settings. There is an even greater scarcity of BCT pilots in the SC field, rendering them important targets for in-depth investigations because the specifics of many pilot implementations are not disclosed to the public; instead, only superficial and unilateral promotion material is available (Wüst and Gervais 2017). Thus, we studied a BCT pilot implementation along supply chains with several actors to gain in-depth insights in order to fulfill this paper's purpose. Because we were able to follow ReLog's BCT application from conception to the project's discontinuation, the case was a solid basis for closely studying how BCT in supply chains is perceived. Thus, we observed ReLog's pilot implementation, which constitutes our unit of observation and all the involved project partners.

Case study

In short, ReLog's aim was to offer a mobile application, with a BCT backend, to enhance traceability along sections of supply chains and to provide end-consumers with product-specific

Figure 1: The synthesized model of interorganizational BCT adoption in supply chains, based on Iacovou et al. (1995) and adapted using Wang et al. (2019).



information such as social sustainability (working conditions), vehicles' environmental characteristics, and the product's touch-points. To allow for this interorganizational traceability and provenance, the solution featured a BC backend to store and retrieve data related to product traceability and sustainability. The mobile application allowed downstream actors to retrieve product information by scanning QR codes or entering product numbers attached to the product. Inspired by Provenance.org and building on a previous crowdsourcing study on social sustainability issues in transportation, the concept of ReLog was first presented at a conference by Anonymized for review[1]-AFR (2016, 2018).

In 2016, a researcher engaged a group of project partners (listed in Table 1, among them AFR) and acquired a nine-month pilot grant of 2 096 00 SEK (US$ 224,000) from the Swedish funding agency Vinnova. In the call for proposals, the principal Vinnova specified that financed projects should aim to accelerate digitalization in the Swedish industry. In 2017, a research coordination organization became the administrative project leader; AFR became the technical project leader; and the university took over the driving role from the research institute. They formed a new consortium (with only some project partners remaining) and received another pilot grant of 1 420 000 SEK (US$152,000) from Vinnova (again for a nine-month project).

The BCT pilot, ReLog, was divided into three phases over 24 months (with project work continuing independent of grants), thus constituting a longitudinal case study with an embedded single-case design involving three units of analysis (Yin 2018). For clarity, it should be noted that the project was not planned to be phased; instead, each phase was an attempt to get ReLog into a running supply chain pilot. Therefore, the consortium followed a trial-and-error approach over the project's duration and was characterized by the willingness to break new ground. The three phases and how the different stakeholders were involved in the product and data flows are outlined in Figure 2.

Following Flyvbjerg (2006) and Ellram (1996), we deployed "the force of example" from a longitudinal single-case study to examine BCT adoption in SCM at an early stage. While the goal of achieving traceability remained for the project's duration, several participants in the consortium (listed in Table 1) as well as the product varied between phases. The BC backend also varied because the solution in Phase 1 was built on one BC backbone (from a BC software company), while Phases 2 and 3 were built on another backbone (from a major technology provider). Therefore, each of the three project phases represents a single unit of analysis for the case study, thus creating an embedded single-case examination.

The main project partners were companies using the BCT-enabled transparency solution to store transaction data along the supply chains. In addition to these main partners, several

[1]In the manuscript, we anonymized one of the authors for the blind review.

Table 1: Overview of involved supply chain actors with associated employees (P1 = Pilot 1, I = informal, F = formal). Formal denotes an actor that was formally part of a funded ReLog project. In addition to these actors, a research institute (first grant), a research coordination organization (second grant), and a university (both grants) were active. AFR was an employee of the university

Supply chain actor	Involved employees and interview partners	Type of actor and role in supply chain
Retailer 1 (P1F)	Head of logistics development Logistics developer Logistics CSR Head of transport purchasing	Primary member, Retailer (selling)
Retailer 2 (P1I)	Logistics developer Terminal manager	Primary member, Retailer (selling)
Logistics service provider 1 (LSP 1) (P1,3I)	Head of quality Logistics developer (2) Head of network planning Account manager	Primary member, LSP (handling, storing)
Logistics service provider 2 (LSP 2) (P2F)	Integration analyst Project manager (2)	Primary member, LSP (handling, storing)
Logistics service provider 3 (LSP 3) (P1I)	Account manager	Primary member, LSP (handling, storing)
Hauler association (P1,2,3F)	CEO Head of member relations	Ancillary member
Hauler 1 (P1F)	Driver	Primary member, Hauler (transportation)
Hauler 2 (P1I)	Driver Terminal manager	Primary member, Hauler (transportation)
Environmental association (P1,2,3F)	Head of freight sustainability certification	Ancillary member
Transport union	Secretary-general	Ancillary member
Transport booking provider (P2F)	Head of enterprise customers Account manager Integration analysts (2)	Ancillary member
Food manufacturer	Global supply chain manager Head of terminal	Primary member, Supplier (production)
Vineyard (P3I)	CEO	Primary member, Supplier (production)
Technology provider (P2F)	Technology executive Nordic blockchain leader Lead architect	Ancillary member
BC software company (P1I)	CEO Lead architect Head of operations	Ancillary member
Technology consultancy (P1,2,3F)	Technical architect Head of innovation Blockchain programmer	Ancillary member

other project partners were specialists (e.g., an environmental association, providing expertise on sustainability certifications and disclosure programs) without participating directly in the supply chain transactions (we refer to these organizations as *ancillary partners*). Yet others (e.g., the Transport Union) supported the project, were anticipated to play a part, and provided ad hoc input; however, they were never involved in any transactions (as illustrated in Figure 2). While the partners in all three phases were willing to test the technology, they were not tied to it. When a supply chain member was considered to give input but did not actually do so, the other project members either provided that partner's input or the programmer hardcoded it into the BCT. The aim of all three phases was to find an adequate solution to make this application work in practice (i.e., focusing on supply chain transparency). This approach provided an objective perspective on the technology itself, in contrast to many other initiatives merely defined by their application of BCT. In conclusion, ReLog was well suited for studying the early adoption process of BCT as IOS in supply chains. Each of the phases had a slightly different emphasis:

- Phase 1 focused on the haulers and the end-consumers.[2]

[2]Long version (in Swedish): https://youtu.be/6VcdIIuCe1Y. Short version (in English): https://youtu.be/nWVdg6KU1MI.

Figure 2: Product and data flow and storage during the ReLog project's three pilot phases.

- Phase 2 focused on the warehousing and LSP operations.[3]
- Phase 3 focused on the supplier and products.

Sampling, data collection, and data analysis

The first pilot phase started in March 2016 and ended in December 2016 (the same time period as the first grant), while the second and third phases started in January 2017 and ended in February 2018. The members, both formal (i.e., officially involved in the project's funded phases) and informal (i.e., participating but not formally involved), varied during the pilots (as labeled in Table 1).

AFR was involved in all the phases and collected data in several spontaneous face-to-face conversations, semistructured interviews, workshops, meetings, and on-site observations. This involvement offered a rare chance to gain in-depth insights from all project partners and to study the BCT adoption along the supply chain from multiple perspectives in three phases. It also enabled trust to be established between the accompanying researcher and the project partners, thus increasing integrity alongside data triangulation (Wallendorf and Belk 1989). Jones and Bartunek (2019) suggest including co-authors in the analysis and writing as an efficient way to mitigate flaws resulting from a researcher being extensively involved in the studied phenomena. While AFR was deeply involved in the project including data collection and initial analysis, the other two authors (experienced in blockchain studies but not involved in ReLog) audited the interpretations from a neutral perspective, in line

[3]Jeppsson & Olsson (2017) reported on Phase 2 in detail.

with Jones and Bartunek (2019). Therefore, all researchers studied the collected data and reviewed the path from data collection to interpretation.

During the time span of 23 months, workshops, meetings (often daily among the core project's team members), on-site visits, and interviews were held. These encounters generated data in the form of workshop and meeting protocols, videos, photographs, and notes from observations and interview transcripts.[4] Therefore, the ReLog case's main data are not post-ante interviews on participants' opinions, but rather interviews reflecting discussions on the potential adoption, that is, reflecting the project's daily work. As a result, the data from workshops, meetings, and on-site visits provided unique and in-depth findings.

Throughout the ReLog project, the lead programmer (employed by the technology consultancy) worked with the BCT providers and conducted weekly tests mimicking supply chain operations using BCT. (The subsection "Illustration of blockchain logic applied" describes some of the outcomes of the tests and technical meetings.) In addition to the previously mentioned data sources, interviews were conducted to gain additional explanatory information to uncover causalities that were not evident before. The open-ended interviews, conducted in either English or Swedish, allowed follow-up questions to the work with the pilot. The interviews were recorded or documented with notes, transcribed (if recorded), and reviewed by the interviewee to achieve content validation. To increase construct validity, the interview data were triangulated with other data sources such as workshop, meeting, and observation protocols and notes as well as web site information. Earlier versions of this manuscript were shown to project members to get feedback and ensure trustworthiness (Wallendorf and Belk 1989).

The data from meetings, workshops, observations, and additional interviews were aggregated in an Excel file, which formed the case study's database. All statements addressing the adoption of BCT in the corresponding supply chains were identified. Similar statements were grouped so that each new statement reported a new item. Subsequently, the items were analyzed to identify overarching clusters, which are presented in this paper's results section with selected statements from interviewees.

ReLog project

ReLog was primarily about creating product traceability in the supply chain by disclosing and logging individual and organizational identities, characteristics, and activities in the BC. As previously mentioned, ReLog resembled the concept behind Provenance.org, a digital platform enabling companies to achieve greater transparency in terms of product origin; however, ReLog focused on the links and nodes between the point of production and the point of consumption, rather than focusing on production itself (see Figure 2). Suppliers (e.g., the vineyard in Pilot 3) entered product data (e.g., bottling data for vine and grape batches). Furthermore, various participants added the following data from their BC transactions: haulers (e.g., first names of drivers and their trucks' environmental characteristics), LSPs (e.g., loading and unloading dates and workers' first names), and retailers (e.g., unloading date). Consumers could read the transaction information by scanning the product's QR codes.

Due to the domain's complexity (e.g., assets, multilevel packaging, shipments, aggregated shipments, vehicles, trailers), the ReLog team chose not to model the domain itself, but instead the language describing it. It was noted that identities, assets, and aggregated assets (packaging, shipments) can be expressed in sentence form (e.g., A has B and C.). The language models a complex domain that can be produced by assuming three ground rules:

- A is either an identity or an asset.
- B and C are assets.
- The word *has* is meant broadly, but its meaning is precise within a context; for example, if A is an identity, *has* means "is current holder of." If A is an asset of type "pallet" and B is an asset of type "package," then *has* means "is part of," etc. We were able to not only accurately describe the whole process but also do some basic automated reasoning about the domain (if A has B and B has C, then A has C.). This design is suitable for a BC application, but can be more easily implemented in a traditional database/private cloud solution.

This data model was heavily influenced by Hyperledger's architecture (The Linux Foundation 2019) and was designed in collaboration with the BC software company, the technology provider, and the technology consultancy. The model records every activity from creating identity/asset to transferring/aggregating/splitting assets. This fact set is huge, but the structure is primitive; these facts form a simple, flat, and time-stamped sequence of documents such as in the fictitious example in Figure 3.

The example in Figure 3 demonstrates each actor's involvement along the supply chain. Figure 3 also identifies each actor's activities step by step and the stored information to outline the scope for handling the products and providing the information.

FINDINGS

Using the previously introduced framework, this section describes this study's conceptual and empirical work. First, we emphasize the positive IOS factors (i.e., perceived benefits, external pressure, and positive readiness). Second, we elucidate the negative IOS factors (i.e., perceived obstacles, external resistance, and organizational immaturity). The findings are organized based on our frame.

Positive IOS factors influencing BCT adoption in supply chains

In Table 2, we summarize the main positive aspects of BCT adoption in supply chains based on our case analysis.

The downstream primary supply chain members wanted to promote their sustainable practices (PB1). The head of Retailer 1's logistics development noted, "Unfortunately we do not capitalize [towards end-consumers] on our sustainable transportation,

[4]Note: Most of the workshops were held in Swedish. Direct citations in this paper are translated into English by the authors.

Figure 3: Logic of blockchain, involved actors, their activities, and stored information.

Logic in blockchain backend	Actors involved	Activity of actors	Information entered
1. Vineyard (VY) creates {wine w: 300} and {wine r: 300}	VY	Attach barcode/OR code to package and upload information	Product name and date and time, use-by date, location, name of VY
2. VY creates {wine box w: 50} and {wine box r: 50}	VY	Attach barcode/OR code to package and upload information	Product name and date and time, use-by date, location, name of VY
3. VY transferred {wine box w: 50} to Retailer 1 (R1)	VY, R1	Scan barcode/QR code during handover of wine box w	Delivery date and location, name of R1, changed ownership
4. VY transferred {wine box r: 50} to LSP1 for transport.	VY, LSP1	Scan barcode/QR code and enter change of ownership	Changed ownership, name of LSP1
5. LSP1 subcontracts Haulier 1 (H1) and transferred {wine box r: 50}.	LSP1, H1	Scan barcode/QR code and enter subcontractors information	Name of H1
6. H1 subcontracts to Haulier 2 (H2) and transferred {wine box r: 50}.	H1, H2	Scan barcode/QR code during handover of wine box r (CF, H2)	Handover date and location, name of H2, driver information
7. H2 delivered and transferred {wine box r: 50} to R1	H2, R1	Scan barcode/QR code during handover of wine box r (CF, H2)	Handover date and location, name of R1, name of warehousing employee
8. R1 aggregated {wine box r: 50}, {wine box r: 50} to {shop_cage{wine box r: 50}, {wine box w: 50}: 1}	R1	Scan barcode/QR code and enter shop and shelf allocation during shop distribution	Shop location, allocation date, shelf location, name of shop employee
9. R1 transferred {shop_cage[{wine box r: 50}, {wine box w: 50}]: 1} to customer (C)	R1, C	Scan barcode/QR code during sale	Sale data and location
10. {shop_cage[{wine box r: 50}, {wine box w: 50}]: 0} is not active (delivered to destination)	None	None	Shelf location cleared
11. {wine box r: 50} is not active	None	None	Item marked as delivered
12. {wine box w: 50} is not active	None	None	Item marked as delivered

but it is definitely on our agenda to do so." They aimed to address their competitive position by increasing visibility, thereby addressing the push to reveal social conditions along the supply chain. Retailer 1 considered itself sustainable when choosing logistics suppliers.

In the ReLog case, the need for transparency, especially for increasing product traceability, and the curiosity to explore and learn about BCT were manifested by the large interest in project participation. Several stakeholders (especially, Retailer 1 and the Vineyard) considered it to be very valuable to enable end-consumers to trace their products' transport sustainability in their journey through the supply chain (PB2).

Further upstream, the supplying companies and the retailers addressed the customers' need for product traceability (EP1). The subcontracted LSP, the associated haulers, and the hauler association were also positive about sharing sustainability information, viewing such sharing as an opportunity both to strengthen ties with customers (including the retailers) and to improve competitiveness (EP2). LSP1's quality manager noted, "...we participate in the project [Transparent transportation/ReLog] where we hope to make it easier for customers to choose the right transporter" (Melander 2017, p. 36). However, the stakeholders knew that this project required the involvement of multiple partners in their supply chain and ultimately in the adoption, emphasizing the BCT solution's network effect to address the need for improving traceability. Hence, the retailers and hauler association persuaded other actors (including suppliers (e.g., food manufacturer) and LSP1) to participate (EP3). The hauler association's head of member relations observed, "We are the only group of haulers following the collective agreements; we are dependent on [LSP1] to stick to their standards." Power in supply chain relations is always important to consider when examining pressure (Fugate et al. 2009; Daugherty 2011). As is often the case, the retailers (shippers) held the power position. LSP2's project manager said, "Our entire business is built around [retailer's name]. If they want it [transparency], we will deliver it; otherwise, it does not make any sense for us to build the capabilities." Moreover, the technology's emergence presented the ideal time to convince internal decision-makers and external supply chain partners.

ReLog was mainly externally funded with the full support and involvement of two tech companies (with both receiving funding in the second grant) as well as a full-time programmer. Hence, initial investment and adequate technical capabilities were provided (OR1, OR3).[5] Several of the actors are also profitable firms with not only advanced IT capabilities (i.e., technically capable of integrating new information systems) but also financial resources to invest in the BCT solution (OR2, OR3). Many of the supply chain members already collected much data on shipment statuses, providing an adequate starting point for inserting tracing data into the system (OR4). To explore piggybacking on an actor with considerable data, the transport booking provider joined the project in the second phase. As the head of enterprise customers noted, "We have all the transport booking data from our customers; if we can help our customers to use it more, it strengthens our business."

As Table 2 demonstrates, all the primary supply chain members identified the perceived benefits. Specifically, organizational readiness and external pressure indicate the discrepancies among the different players. While the research funding was advantageous for everyone involved, additional required financial

[5]Two rounds of external funding totaled 3.52M SEK, that is, about $377,000 (1US$ = 9.32 SEK, as of December 20th, 2019).

Table 2: Factors positively influencing the decision to adopt BCT in the supply chain (Primary members denote supply chain actors actually handling the goods.)

Positive IOS factors	Reasons	Associated actors
Perceived benefits (PB)		
PB1. positive awareness of sustainability	Provided possibility of sharing information with end-consumers about environmental and social sustainability	All primary members
PB2. increased product traceability	Enabled tracing product and offered consumers valuable insights on the product's life cycle	All primary members
PB3. enhanced trust	Allowed building a basis for trust among unknown supply chain actors based on enhanced transparency	All primary members
External pressure (EP)		
EP1. need for product traceability	Responded to the customer demand to increase product traceability	Suppliers, retailers
EP2. push for revealing social conditions	Improved competitive position by entering data into the BCT solution, thus increasing visibility	LSP, haulers, union
EP3. need for improving traceability	Actively working with improving traceability (improved status updates for shipments) was desired by several stakeholders, motivating them to push other actors to participate.	Suppliers, LSP
Organizational readiness (OR)		
OR1. initial investment	Cost for initiation supported by research funding	All
OR2. sufficient financial resources	Actors' ability to invest in the BCT solution (financially strong)	LSPs
OR3. adequate technical capability	Actors' IT capabilities, helping adopt the technology in these organizations	Retailers
OR4. data availability	Sufficient availability of data, making the BCT solution easier to use	Retailers, transport booking provider

resources, technical capability, and data availability were not provided for all the project participants. This is true when examining external pressures, which are actor-specific and do not apply to all actors. Therefore, the importance of studying BCT adoption both on the intrafirm and the interorganizational levels is reemphasized.

Negative IOS factors influencing BCT adoption in supply chains

Table 3 presents negative factors in the ReLog project that influenced the decision to adopt BCT in supply chains.

The integration analyst (transport booking provider) outlined a major challenge: “I do not want to be the party pooper, but it is going to be a struggle to have the workers update the statuses. Already today, with much fewer statuses than you anticipate in a transparent supply chain, the firms are struggling to keep the status of the shipments correct.” This integration analyst was right. All actors struggled with the human factor and time pressure in entering data in the pilot system. During the ReLog pilot phases, the data entry (e.g., scanning barcodes) was often forgotten. In some processes, data entry involved considerably more time than before, thus decreasing operational efficiency (PO1). In Phase 3, the supplying vineyard’s CEO said, “There is no chance whatsoever that I will manage to do this [scanning boxes and bottles] in high season.” Without the supporting infrastructure that would allow for automated scanning, the data collection created additional work that consumed more time and was perceived as an annoying task for the workers (PO2).

From the technology perspective, IOS like BCT poses compatibility problems. The technology must be compatible not only with the organization (for organizational compatibility see organizational readiness) but also with the existing information systems that write and read to the BC, a more difficult task for legacy production systems and embedded systems, as experienced in the ReLog project (PO3). It cannot be expected that the present BC systems (such as Hyperledger Fabric, R3 Corda, or Ethereum) will be capable of seamless synchronization or that a specific system will be established or emerge as the de facto industry standard. Clearly defined industry standards, which are currently missing, could minimize barriers to BCT adoption (Korpela et al. 2017).

The transport union emphasized that although it is generally positive about enhancing transparency (especially visibility of collective agreements), the transport workers’ privacy must be investigated more thoroughly before a large-scale adoption can be fully supported. According to the transport union’s secretary-general, “In order for this to fly, we need to have some clear benefits for our members; otherwise, we cannot just give in to increased monitoring, which this, in practice, means.” The drivers were likewise skeptical about having their identities and names shown (ER1).

Given the challenging IT operations needed and the lack of standardization to tackle this challenge, several parties lacked the commitment for successfully adopting the novel technology (ER2). Against the backdrop of multiple and rival business relationships, the lack of standardization posed a substantial barrier because several stakeholders were unwilling to invest too much effort in an individual supply chain (ER3). In addition, the stakeholders had to invest in IT trainings for the workers and operators of the new BCT solution, which presented another obstacle, especially for the vineyard and the LSPs (OI1).

Table 3: Factors negatively influencing the decision to adopt BCT in supply chains

Negative IOS factors	Reasons	Associated actors
Perceived obstacles		
PO1. decreased operational efficiency	BCT solution requires gathering additional data on a batch level (e.g., scanning parcels) for uploading.	All primary members
PO2. incurred nuisance	Employees consider scanning/typing to be annoying.	All primary members
PO3. increased IT handling complexity	Operating additional interfaces (data entry into BCT) lead to additional complexity (e.g., in a legacy architecture) and require new IT routines.	All primary members
External resistance		
ER1. industry stakeholder resistance	BCT solution reveals personalized data to others (e.g., personal information about frontline SC workers is disclosed).	All primary members' workers, hauler association
ER2. external lack of commitment	Transparency of sustainability information is of minor importance inside the firms, resulting in minor willingness to make significant process and system alterations and to deal with lack of standardization.	All primary members
ER3. rival business relations	All participants were part of multiple supply chains, with limited interest in making disproportionate efforts in one selected supply chain.	All primary members
Organizational immaturity		
OI1. necessary IT training investments	Operating the BCT solutions requires additional IT capabilities that must be developed.	Supplier, LSP
OI2. needed infrastructure	Deploying the BCT solutions requires additional infrastructures (e.g., scanners and Wi-Fi connection) to fully capture data.	All primary members
OI3. increasing coordination demand	BCT solution requires jointly establishing data standards for data upload and agreeing to those standards.	All
OI4. required openness	BCT solution discloses actor-specific data to other supply chain partners and customers (e.g., warehouse processing of LSPs).	All primary members

The large-sized (in terms of employees) primary members of ReLog used legacy systems. Such systems rely heavily on relational databases and synchronous transactions, thus changing their foundation is much more complex, relatively speaking, than a regular system's integration/extension (Wüst and Gervais 2017). LSP1's internal consultant said, "We have been working on implementing our ERP system for 12 years; we cannot do any changes to the architecture for a long time." Thus, creating a system integration for a specific goods' flow (i.e., connecting it to an atomic BC) with existing legacy systems is very challenging. On the other hand, the small primary members were not burdened by legacy systems, but lacked strategic IT management.

The decreased operational efficiency (outlined previously as PO1 and PO2) could have been addressed with automation through, for example, NFC, RFID, Bluetooth, or image recognition cameras. However, these solutions would have required substantial changes in the hardware and software IT infrastructure, including the ERP systems, thus presenting an enormous obstacle for all the primary supply chain members (OI2).

As previously emphasized, many of the participants considered transparency in the supply chain to be the ReLog project's most important contribution. However, this contribution was not linked to the BCT per se because such a solution can also be provided using traditional relational databases (Wüst and Gervais 2017). The actors in the ReLog project did not confirm the relative advantage of the degree to which BCT was perceived as being better than the established systems. In one meeting, the lead programmer described the application: "BC creates digital trust, not physical monitoring; actually, it says nothing about the characteristics of the product." In the same meeting, the lead programmer used the previous sample ledger (Figure 3):

If VY creates a {wine r: 210} that is not actually a true red wine but rather grape juice, the ledger does not help us. We can see the history of transactions related to {wine r: 210}, but we cannot know how or where the fake red wine, in this case a red grape juice, entered the supply chain (cf. GIGO challenge by Babich and Hilary 2019). Thus, the trust of the authenticity of {wine r: 210} can never be greater than the trust we have for actors R1, VY, C, LSP1, and H1 and H2.

Six members is a low number in real-world supply chains. All these actors must ensure that all updates are executed perfectly because any BC application is dependent on a stable state, which will become highly complex in a network (OI3).

Finally, the project revealed that a BCT solution required increased openness from the primary members. In a Phase 1 workshop, one of Retailer 2's project managers stated, "We already have very good data; as we control the whole supply chain already today, we are not interested in sharing additional data with other parties." ReLog failed to present enough value to motivate increased openness (OI4).

DISCUSSION

In this section, we first contrast BCT adoption's pros and cons and elaborate on the tensions revealed in the empirical data. Second, we discuss whether the findings are transferable to other supply chain settings.

Tensions regarding BCT adoption in supply chains

This paper uses IOS adoption theory (Iacovou et al. 1995) to answer the research question of why, despite the promising benefits outlined by previous studies, supply chains struggle to adopt BCT. Our analysis reveals that several trade-offs exist between positive and negative IOS factors that cannot be resolved. The trade-offs stem from the relationship between positive and negative IOS factors because realizing some of the positive IOS factors also entails negative IOS factors at the same time. These trade-offs lead to tensions between opposing perceived adoption factors. To provide a holistic understanding of BCT adoption in supply chains, these tensions must be considered.

Positive awareness of sustainability (PB1) and enhanced product traceability (PB2) were incentives for participating project members. The project members saw the novel technology as an opportunity to enhance transparency in their supply chain and to offer customers sustainability insights into the product's journey along the supply chain. Therefore, they shared the same opinion on the BCT benefits as proposed in recent studies (e.g., Kshetri 2018). At the same time, data entry's operational cost was a big barrier (PO1, PO2), causing a *traceability-efficiency tension* between PB1/PB2 and PO1/PO2. While some primary members (including retailers and the transport booking provider, see OR4) had all the data in place, others struggled to provide the data and faced a substantial additional workload or infrastructural investments (see OI2) to provide the relevant data (e.g., vineyard, see PO1 and PO2). In addition, the process of data entry would require standardization, thus amplifying obstacles PO1 and PO2. Only a few scientific studies have addressed this topic (e.g., Korpela et al. 2017; Wang et al. 2019). While focusing on the function of BCT and the data within, many studies have omitted the data input. As the ReLog case indicates, such an omission—when supply chain actors are unable or unwilling to provide the required data—can be a deal breaker.

The participating associations (haulers' association, transport union, and environmental association) were generally positive about creating awareness of the working conditions in the supply chain and saw such awareness as advantageous for their competitive position (EP2). This finding aligns with that of Mol (2015) and Marshall et al. (2016), who emphasize improved visibility's positive effect on customers' sustainability perceptions. However, the transport union in particular was critical to the privacy of supply chain frontline workers (ER1), in addition to improved visibility, allowing for more monitoring. The solutions require openness to make processes visible (OI4), which in turn can also have negative effects, such as data leaks (Wüst and Gervais 2017). According to Clemons and Row (1993), data leaks within IOS can potentially lead to reduced bargaining power. Thus, the *visibility-privacy tension* emerges, manifesting that visibility; even though it is intended to improve sustainability, it limits individuals' privacy. Disclosing information, such as the processing LSP employee, would allow different employees' performance to be assessed based on the number of processed products and, thus, would constitute a significant obstacle for employee organizations.

Next, the study revealed a paradox, which is a special case of tension (Smith and Lewis 2011; Wilhelm and Sydow 2018). A *paradox* refers to elements that seem logical when considered in isolation, but which are irrational or inconsistent when juxtaposed. Enhanced trust (PB3) is not only a perceived benefit of BCT in that special case but also a central value proposition of BCT in supply chains (Saberi et al. 2019) and a major challenge in supply chain networks (Daugherty 2011). Honesty-based credibility stresses the exchange partner's integrity, for example, in terms of sincerity (Asare et al. 2016). The data are secure in the BC; that is, the data cannot be manipulated by a supply chain actor. However, as illustrated before (cf. Figure 3 and OI3), the BC does not ensure that the correct data were entered into the ledger. One of BCT's promises is being a "trust machine" (Beck et al. 2016; Clemons et al. 2017). However, to establish a BCT-enabled IOS in a vertical supply chain setup (Babich and Hilary 2019), a long-term relationship (which in turn assumes that trust exists based on positive experiences over time) is necessary. If trust already exists among the supply chain actors, BCT-enabled trust does not offer any significant value to the relationships. Hence, the *trust-investment paradox* (PB3 vs. OI2/3) arises. On the one hand, the supply chains that need trust cannot implement the technology due to lack of trust. On the other hand, the supply chains with well-established relationships that can implement a BCT solution do not need additional trust. This paradox is a unique finding in BCT literature. Scholars have thought that the novel technology would enhance the use of spot markets because trust can be established earlier without long-term relationships (e.g., Catalini and Gans 2016; Seidel 2018). However, these contributions have focused on BCT's core function and have been misguided regarding interorganizational adoption and integration that require long-term investments.

Finally, the broader *performance-commitment tension* was discovered. While the members saw PB1, PB2, and PB3 as performance improvements by adopting the BCT solution (given their interest in promoting their own sustainability), they were also aware of the significant commitment required—that is, training employees (PO3) and improving their IT capabilities (OI1). In addition, the pilot required commitment to establish common standards for data processing, which also limited each actor's freedom and room for maneuvering. Moreover, the need for coordination (e.g., for administering and verifying an organization's BCT identity) (OI3) made the team realize that the ReLog project would have to continue beyond implementation in order for the supply chain actors to productively use BCT. Hence, the actors had to commit not only to their supply chain relations but also to the new intermediary/ies, the BC software administrator (ReLog), and/or the selected technology provider. For some supply chain actors, enhancing transparency was not a high priority (ER2), and initiatives in other, more important supply chains

Table 4: Tensions of BCT adoption in supply chains

Tensions	Reasons	+ (pros)	− (cons)
Traceability-efficiency	To realize enhanced product traceability's perceived benefit, supply chain actors must overcome the hurdles of inefficiencies largely resulting from organizational immaturity.	PB1, PB2	PO1, PO2, OI2, OI3
Visibility-privacy	To enhance visibility in their supply chain and reveal their sustainability awareness, supply chain actors must respond to data privacy concerns of workers and supply chain partners.	PB1	ER1, OI4
Trust-investment (paradox)	To enhance trust by using BCT-based solutions, supply chain actors must invest in the technology, which, in turn, is only attractive when long-term trust among supply chain partners is already established.	PB3	OI1, PO3, OI2
Performance-commitment	To enhance product traceability, visibility, and trust, supply chain actors' long-term commitment is required to establish capabilities, which, in turn, depends on the BCT solution's importance and the associated supply chain.	PB*	PO3, OI1, OI3, ER2, ER3

Note: * = denotes all.

resulted in a lack of commitment (ER3). When considering the network effect of a BCT solution that enhances transparency in supply chains, a broad commitment is critical for such a solution's success. According to Saberi et al. (2019), lack of collaboration can represent a barrier for BCT, and fragmented product traceability substantially reduces the perceived benefits (PB1, PB2, and PB3). The ReLog case also reveals that in addition to setting collaborative standards, supply chain actors' commitment threatens the realization of perceived benefits and, thus, leads to this tension. Table 4 lists the four major tensions found in our research.

All four tensions result from unresolved positive and negative IOS factors. Organizational readiness and external pressure positively influence supply chain actors' intentions to adopt BCT solutions (e.g., OR*); these factors do not lead to tensions. Instead, especially the positive determining factors of organizational readiness (OR*) can be understood as requirements to adopt BCT. In case they are not present (e.g., as in the vineyard's scanning example), these factors must be addressed to successfully adopt BCT (e.g., by investing in automated barcodes or RFID scanners). Furthermore, the determining factor of external pressure encourages or even forces technology adoption.[6]

Model transferability

In contrast to, for example, cryptocurrencies (horizontal applications of BCT), supply chains represent a vertical application area of BCT. Although more research is needed to test the proposed model, it is very likely that heterogeneous supply chain actors will face tensions similar to those in the ReLog case. This assumption is based on both the case and the promised benefits and obstacles identified in the literature. The ReLog case not only provides unique access to an actual BCT project but also has breadth and depth through numerous stakeholders and its long duration. Moreover, the model can be transferred to the adoption of interorganizational IOS and other technologies requiring a high degree of adoption along the supply chain. Therefore, this model is likely applicable for all vertical BCT applications in supply chains such as end-to-end traceability or transport applications.

[6]As of August 2019, the ReLog project was on hold because of these challenging tensions.

CONCLUSIONS

Revisiting our goal and research question, we present the main insights from our research in light of the interorganizational system's adoption and recent literature on blockchains in SCM. Aligning with previous research on IOS adoption (Iacovou et al. 1995), we propose that the adoption of BCT in supply chains can be determined by considering economic, organizational, and environmental factors. Informed by BCT's benefits and challenges in supply chains, both the positive and the negative IOS factors are important to consider. Furthermore, our discussion highlights the tensions arising between positive and negative IOS factors of adoption.

Managerial implications

Our research insights aid practitioners in objectively viewing the potential effects and adoption obstacles to a BCT-based information system in their supply chains. The in-depth elucidation of the ReLog project also provides a pedagogical introduction to supply chain majors wanting to understand blockchains' underlying mechanisms as an approach to capture BCT's state.

Given that logistics magazines and SCM news are filled with information from blockchain startups and given the costs associated with blockchain pilots (e.g., one technology provider charges from $300,000 to $400,000 for a basic supply chain pilot), this paper provides helpful insights into what blockchains in supply chains can and cannot leverage in terms of transparency and trust. Decision-makers who understand the BC trust-investment paradox introduced in this paper can save resources by avoiding exaggerated expectations and failed projects that may not yield novel insights.

Finally, while implementing BCT in supply chains, managers should be aware that they must maneuver in complex circumstances, especially in addressing several specific tensions. Decision-makers should not overemphasize the promised benefits of BCT adoption in their supply chain; instead, they must be aware of the obstacles, such as those empirically outlined in this paper, that are outside the decision-makers' control. With BCT's benefits in supply chains being mainly network effects, decision-makers must ensure the ability and willingness of all the involved internal stakeholders and external supply chain partners to implement such an IOS. BCT's full impact in supply chains can only be realized when the technology has been adopted along the supply chain without major exceptions and gaps; otherwise, the BCT initiative will fail. The list of tensions in the potential adoption outlined in the ReLog case provides important considerations for SC managers attempting similar implementations.

Theoretical implications

While explaining why supply chains are struggling to adopt BCT, we contribute to theory in several ways. First, this paper conceptualizes the adoption of BCT in supply chains by drawing from IOS adoption theory and empirically expanding on previous conceptual work. We emphasize that BCT's anticipated impacts in supply chains are network effects dependent on a critical mass of adopters. This dependency could serve as a basis for future examinations, thoroughly analyzing the nature of BCs' network effects in not only vertical but also horizontal or diagonal network settings (Babich and Hilary 2019).

Second, we contribute midrange SCM theory by introducing a model of the factors determining IOS adoption of BCT in supply chains. The model specifies not only perceived benefits, external pressure, and organizational readiness (positive IOS factors) but also perceived obstacles, external resistance, and organizational immaturity (negative IOS factors) as well as how these factors affect the willingness to adopt an IOS (such as BCT) in supply chains. Based on this foundational work, future research can potentially elaborate on specific configurations of BCT application areas beyond the physical supply chain (e.g., supply chain finance) or on other IOS applications in the supply chain context (e.g., packaging systems spanning multiple competing organizations).

Third, several trade-offs of interorganizational BCT adoption were identified. Therefore, the study empirically derived the *trust-investment paradox* as well as the tensions *traceability-efficiency*, *visibility-privacy,* and *performance-commitment* as specific phenomena of BCT adoption in supply chains. Thus, we emphasize the importance of simultaneously studying positive and negative adoption factors for all relevant supply chain actors. While contributing to literature on paradoxes in SCM (e.g., Wilhelm and Sydow 2018), we are also proposing an interorganizational adoption model that can guide future research. The tensions among positive and negative IOS factors merit future investigation to expand the understanding of interorganizational BCT adoption in supply chains. Based on our findings, both SCM scholars and practitioners are able to address how to handle these tensions. A relevant factor to consider is the specifics of supply chains, typically involving several layers of outsourcing and many small- and medium-sized enterprises with limited capabilities of adopting innovations (Wagner 2008). Because BCT's dissemination in practice is still in its infancy, in-depth case studies or cross-case studies of future successful implementations as well as science-based research (Holmström et al. 2009) seem to be appropriate methodological approaches for such investigations.

Finally, we have elaborated on trust, using ReLog's vine supply chain as a sample and, thus, raising the question of how we know that the information in the blockchain accurately represents the state of the physical world. Due to technical and human errors, the digital world often inaccurately represents the physical world's state. This misrepresentation is an interesting challenge to examine by considering the aforementioned logic of identities and by trying to determine whether the identities in the supply chain's blockchain correspond to physical identities. This issue should be addressed regarding not only social sustainability issues in supply chains (Marshall et al. 2016) but also increased digitalization of supply chain work. On a similar note and in light of strong unions and worker retention, we emphasize that privacy concerns (including those of supply chain workers) present an important BCT issue in supply chains from a human-centric perspective.

Limitations and future research

Although our research design is a good fit for our research question at this early stage of BCT adoption in supply chains, our explorative single-case study has limitations opening avenues for future research. As for all single-case studies, our findings' external validity must be tested by future research. Thus, generalizability is limited, presenting an opportunity for future research to study different BCT applications (e.g., trade finance applications) in supply chains. Moreover, our case study potentially suffers from subjective interpretations. While one of the authors was engaged in the ReLog project, the other authors functioned as auditors to reduce this potential subjectivity. Thus, future approaches should test our framework and elaborate on our findings.

Aside from our methodological limitations and beyond our case study's findings, we see the additional need for research in relation to BCT in SCM in the broader sense. Future research must address the management of distributed ledgers and BC platforms in multi-actor supply chains. Specifically, more efforts should be devoted to managing data governance (Mattila et al. 2016), sharing responsibility for such a platform ecosystem, and establishing standards to enable the use of multiple BCT applications in interorganizational supply chain settings. The following questions should be explored: *Are new or existing actors in the ecosystem going to take responsibility? Is disintermediation going to affect or even disrupt supply chain actors, as some experts are suggesting* (Gupta 2017; Mabe 2018)? Additionally, interoperability strategies are necessary to provide several BCT solutions juxtaposed in the supply chain. In terms of technology, future research should investigate the suitability of noncritical transactions, such as commodity shipments because BCT was initially developed for banking transactions, and some research suggests it should not be used for supply chains (Wüst and

Gervais 2017). Very few articles about BCs highlight the enormous redundancy of data blockchains with many nodes generated and the related GIGO problem (Babich and Hilary 2019). However, regarding BCT's financial applications, the assets' tokenization should be studied, especially in the context of supply chain financing.

Babich and Hilary (2019), among many others, state that BCT is hyped. Thus, practitioners as well as researchers should have a critical attitude about the technology's promised benefits. We hope to have contributed a path toward balancing the positive and negative IOS adoption factors and what to consider while maneuvering amid tensions. Has BCT failed in supply chains? Although it is not over till it is over, justifiable doubts exist, as the elaborated struggles of our case indicate.

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