logistics

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The Supply Chain Has No Clothes: Technology Adoption of Blockchain for Supply Chain Transparency

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Received: 21 September 2017; Accepted: 28 December 2017; Published: 5 January 2018

Abstract: Blockchain technology, popularized by Bitcoin cryptocurrency, is characterized as an open-source, decentralized, distributed database for storing transaction information. Rather than relying on centralized intermediaries (e.g., banks) this technology allows two parties to transact directly using duplicate, linked ledgers called blockchains. This makes transactions considerably more transparent than those provided by centralized systems. As a result, transactions are executed without relying on explicit trust [of a third party], but on the distributed trust based on the consensus of the network (i.e., other blockchain users). Applying this technology to improve supply chain transparency has many possibilities. Every product has a long and storied history. However, much of this history is presently obscured. Often, when negative practices are exposed, they quickly escalate to scandalous, and financially crippling proportions. There are many recent examples, such as the exposure of child labor upstream in the manufacturing process and the unethical use of rainforest resources. Blockchain may bring supply chain transparency to a new level, but presently academic and managerial adoption of blockchain technologies is limited by our understanding. To address this issue, this research uses the Unified Theory of Acceptance and Use of Technology (UTAUT) and the concept of technology innovation adoption as a foundational framework for supply chain traceability. A conceptual model is developed and the research culminates with supply chain implications of blockchain that are inspired by theory and literature review.

Keywords: blockchain; innovation; traceability; provenance; supply chain management; transparency; trust; Unified Theory of Acceptance

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1. Introduction

Blockchain technology is generating a big stir in logistics and supply chain management. This particular technology received initial attention for its association with Bitcoin [1] and its capability to create a trusted and transparent ledger of transaction information. Now, as supply chain managers begin to recognize the possibilities of this new technology, there is high potential for elevating transparency. The arrival of this technology is timely because consumers are demanding supply chain transparency. For example, consumers often want guarantees that fish purchased and consumed are not farmed using illegal netting practices or from closed waters [2]. Also, jewelry consumers want assurance that purchased diamonds are authentic and not farmed from war-torn regions of the world. These concerns are exacerbated when supply chains are multi-tiered and increasingly global in scope. Blockchain technology promises to dramatically change transaction methods by providing a transparent and immutable record for inspection, bringing to mind the classic tale "The Emperor's New Clothes" by Hans Christian Andersen. Currently blockchain applications are primarily being used and developed within the finance sector [3–5], but the popular press and supply chain managers have taken notice and are quickly applying the technology to customer service and achieving competitive advantages.

Awaysheh & Klassen [6] identify transparency as the extent to which information is readily available to both counterparties in an exchange and also to outside observers. In a supply chain context, transparency refers to information available to companies involved in a supply network. Supply chain traceability leverages transparency to operationalize organizational goals related to raw material origins and provide context to a final product or service. Blockchain technologies indeed provide increased supply chain transparency, but more importantly create an immutable and distributed aspect of the custody record by nature of the protocol which lends itself well to traceability applications.

Scholars have identified that optimizing transparency and traceability are correlated. Skilton & Robinson [7] identify traceability (synonymous with "provenance"—derived from French referring to "the origin of something") as the ability to identify and verify the components and chronology of events in all steps of a process chain. The relationship between supply chain transparency and traceability is not straightforward and linear: while having more information available (i.e., transparent) may lead to increased traceability; increased traceability may not lead to increased transparency if the supply chain is made of few participants with loose affiliations.

Traceability is hindered when material information is incomplete or missing; however, the merits of traceability are limited by the complexity within the supply network. For example, a single source producer of coffee beans is less complex than a multinational conglomerate that aggregates the beans from several producers from several countries. The complexity of supply chain networks comprised of different actors (i.e., raw material suppliers, distributors, manufacturers, retailers, and end consumers) consists of concealed elements and raises questions of effective and secure monitoring. Markman & Krause [8] suggests that supply chain scholars are among the most qualified to address these concerns due to their holistic view of the value chain.

Due to the infancy of blockchain, it is poorly understood and the intent to adopt it for supply chain traceability is unknown. Furthermore, despite the hype and possibilities, even the most innovative, technically superior technologies are rendered useless if they are not adopted by the users [9]. For this reason exploring and studying the issues of consumer technology adoption have been discussed in a variety of domains. Within the marketing and logistics literature, Flint [10] defines innovation not as something new to the world, but as being new to the user and subsequently affirms a "voice of the customer" approach to logistics innovation and emphasis of the dynamic inter-organizational interface with customers. The goal of this article is to explore the adoption of users of blockchain technologies in supply chain traceability applications. Using the Unified Theory of Acceptance and Use of Technology (UTAUT) as a framework for technology acceptance and the construct of information technology trust, a conceptual model with researchable propositions is developed. The research culminates with supply chain implications of blockchain inspired by theory and literature review.

2. Background and Literature Review

2.1. Blockchain

Blockchain uses mutually distributed ledgers that have been built on a series of innovations used for organizing and sharing digital data. As defined by Seebacher & Schüritz [11],

> *"A blockchain is a distributed database, which is shared among and agreed upon a peer-to-peer network. It consists of a linked sequence of blocks (a storage unit of transaction), holding timestamped transactions that are secured by public-key cryptography (i.e., "hash") and verified by the network community. Once an element is appended to the blockchain, it cannot be altered, turning a blockchain into an immutable record of past activity."*

The process of "hashing" transforms tangible (e.g., raw material) and intangible (e.g., ownership of a file) assets into a digitally encoded "token" and can be registered, tracked, and traded with a private key on a given blockchain. Further control of an asset may be achieved and supply chain traceability may be enabled through use of tracking technologies such as RFID, NFC tags, and similar technologies enabled by the Internet of Things (IoT). As demonstrated by Bitcoin, the technology underlying the digital currency constitutes a proven, effective mechanism for achieving distributed consensus in a dynamic, unreliable networked environment of untrusted participants [12,13].

A particular feature of operating in a digital environment is the possibility of creating algorithms and programs that can be partially or fully executed or enforced when certain conditions occur without human interaction—a feature known as "smart contracts" [4]. A "smart contract" is activated once a pre-set condition or set of conditions agreed to by the parties in involved are triggered and all partied informed (or updated) per the contract. An example is the systematic notification and payment for automated escrow.

Hofmann & Rüsch [14] suggests blockchain will help facilitate further supply chain integration. Nonetheless, for industries and firms already well integrated, they may not be willing to substantially invest in blockchain that does not provide significant benefits over present solutions. Much is still yet to be learned about this emerging technology.

2.2. Supply Chain Transparency

Similar to supply chain traceability, the supply chain concept of transparency embodies information readily available to end-users and firms in a supply chain. Lamming [15] indicates that there are varying degrees of supply chain information sharing (also referred to as "visibility") within the supply chain. Lamming refers to it as transparency and that supply chains need to transparently supply all actors with knowledge, normalizing information leverage during negotiations and providing more information about component origins and processes. See Figure 1.

	Opaque	Translucent	Transparent
Business case (information shared between two organizations)	For any of a variety of reasons, no information is shared between the parties; even operational day-to-day information is obscured	Outline information only is shared – interface conditions or partial data. This can be similar to "black box" collaborative design. If used tactically, it may be akin to cheating	Information is shared on a selective and justified basis. Development of information leads to shared knowledge and collaborative abilities

Figure 1. Information Transparency [15].

Awaysheh & Klassen [6] suggest supply chain transparency drives the adoption of supplier socially responsible practices to both influence customer purchase behavior and create conditions that force competitors to match their actions, especially for managers with valuable, high visibility brand names. However, high-profile companies such as Apple have followed a policy of secrecy about component sourcing and practices [8] and only released information after extensive social pressure [16].

According to the United National Global Compact on Traceability [17], traceability is not a substitute for corporate due diligence to uncover potential adverse impacts. Some companies with a robust understanding of their supply chains and supply chain partners have their own traceability protocols, often for high value or strategic items. For other industries with a wide and disparate multi-stakeholder framework such as agriculture and most manufacturing, several traceability frameworks exist to develop credible and robust chain of custody standards and certification for products along the supply chain:

- Product Segregation model: certified materials and non-certified materials are not mixed (e.g., Fairtrade coffee)

- Mass Balance model: certified and non-certified materials can be mixed where segregation is very difficult or impossible to achieve (e.g., cotton yarn)
- The Book and Claim model: does not seek to have traceability at each stage in the supply chain. The model relies on the volume of the certified material produced at the beginning of the supply chain and the amount of certified product purchased at the end of the value chain. Sustainability certificates are bought via a trading platform (e.g., UTZ Certification).

2.3. How Blockchain-Enabled Traceability Applications Work

The characteristics of blockchains make them especially suited for traceability applications. Whenever goods and related documentation (e.g., bills of lading or ship notifications) pass from one actor in the supply chain to another, items are subject to counterfeiting or theft. To protect from this, blockchain technology involves the creation of a digital "token" which is associated with physical items when they are created. The final recipient of the item can then authenticate the token which can follow the history of the item to its point of origin. End users have more confidence in the information they receive since the no one entity or group of entities can arbitrarily change the information contained within the blockchain.

Due to most goods' linear flow from material origin to final consumer, blockchain is a suitable technology to enable supply chain traceability. Since goods and their associated "tokens" usually are not traded between competitors within in a given blockchain, this operational facet helps maintain anonymity. As such, participant confidentiality may be maintained.

2.4. Current Blockchain-Enabled Supply Chain Traceability Applications

The first traceability application evaluated is a project enabled by Ethereum [18]. From January to June 2016, yellowfin and skipjack tuna fish were tracked throughout the entire supply chain, from fishermen to distributors. End users could then track the "story" of their tuna fish sandwiches via a smartphone and determine information about the producers, suppliers, and procedures undergone by the end product. Every unit of measure (by fish or by catch) was associated with a digital "token" to confirm a given fish's origin and tracked throughout the supply chain, presenting a viable model for product certification to an end consumer.

Everledger [19] is another blockchain enabled traceability application for the global diamond industry. The company, which partnered with Barclays, created a database of over a million diamonds registered on their blockchain to certify the final cut diamond was ethically-sourced from "conflict free" regions. Similar measures are being used to create an anti-counterfeit database for other valuable goods such as fine wine and art.

3. Theoretical Basis

3.1. The Unified Theory of Acceptance and Use of Technology

The Unified Theory of Acceptance and Use of Technology (UTAUT) was developed through the review and integration of eight dominant theories and models, which are listed in Table 1. Individually, each theory has been used extensively within several academic disciplines to research individual use and acceptance of information technology. Venkatesh, et al. [20] synthesized these alternative views on user and innovation acceptance and created the UTAUT framework based on a six month study of four organizations. The study revealed that the contributing models explained between 17 and 53 per cent of variance in user intentions; however, UTAUT was found to outperform the eight individual models. For a comprehensive literature review see Williams, Rana, & Dwivedi [21] who examined 174 existing articles on the UTAUT model. These authors empirically demonstrate its soundness as a methodology for explaining individual technology acceptance and use in organizations across a variety of organizations, geographies, and applications.

The UTAUT model presents four main effects for end intention and usage which are performance expectancy, effort expectancy, social influence, and facilitating conditions. The UTAUT identified the four moderators of gender, age, experience and voluntariness of use, but these associations were based on empirically observed correlations rather than on theory and are not included in the resulting conceptual framework. The original four core determinants and respective associations were maintained for this article as they have proven to be reliable determinants in prior research.

Table 1. Theoretical Origination of UTAUT.

#	Theory	Source	Description
1	The Theory of Reasoned Action (TRA)	Ajzen & Fishbein [22]	TRA is used to predict individual behavior based on pre-existing attitudes and intentions
2	The Technology Acceptance Model (TAM)	Davis [23]	End user use and acceptance model
3	The Theory of Planned Behavior (TPB)	Ajzen [24]	TPB is the first model to mention psychological factors related to technology acceptance
4	A combined TBP/TAM	Taylor and Todd [25]	These authors added two factors (subjective norm and perceived behavioral control) to TAM which gave a more complete test of important determinants of technology usage
5	The Model of PC Utilization	Thompson [26]	A competing perspective to TRA and TPB used to predict usage behavior rather than intention to use
6	Diffusion of Innovation Theory (DIT)	Rogers [27]	DIT describes how technological innovation moves from invention to widespread useage
7	Social Cognitive Theory (SCT)	Bandura [28]	Stipulates environmental influences (e.g., social pressures) or unique personal factors (e.g., Personality) are equally significant in determining behavior
8	The Motivational Model	Davis [29]	The core constructs of the theory are extrinsic and intrinsic motivation

3.2. The Concept of Technical Innovation Adoption

Behavioral intention and use behavior are strongly influenced by trust. Trust is identified as an important factor for supply chains to function effectively due to the inherent information interdependencies between organizations. It stands to reason that a firm is only as trustworthy as its business partners, because in many industries the manufacturer relies on a network of channel partners of suppliers and distributors that influence a firm's brand image and customer relationship.

Trust is a key element of blockchain technology: not between the participants involved, but of the information integrity contained within the blockchain. The distributed nature and data integrity promised by blockchain enables members with no established relationships to transact with a high degree of confidence based on the information available from the blockchain. This is important for managers because the ledger become one version of the truth whereby all the transactions between counterparties produce an audit trail and settle disputes quickly. Additional implications include a potential decreased need for intermediaries and labor intensive audit, thus minimizing errors.

Lippert [30] provides a construct to frame trust with respect to technology innovation adoption that includes two types of trust: trust of technology and inter-organizational trust. During the development of the conceptual model in the next section, two sections will examine these independent types of trust. Section 4.6 will introduce trust of technology and Section 4.7 will introduce inter-organizational trust.

4. Conceptual Model

This research develops a conceptual model based on UTAUT. The model provides theoretical guidance for the development of research propositions for the adoption and use of blockchain technologies applied to supply chain traceability. The conceptual model utilizes six of the influential variables from UTAUT.

Additionally, this research introduces two trust constructs of IT innovation adoption which are germane to exploring the promise of blockchain's inherent qualities of supporting transparency via "trustless" trust. The following propositions explore the relationships between the research variables that comprise the decision model to use blockchain for supply chain providence. See the conceptual model in Figure 2.

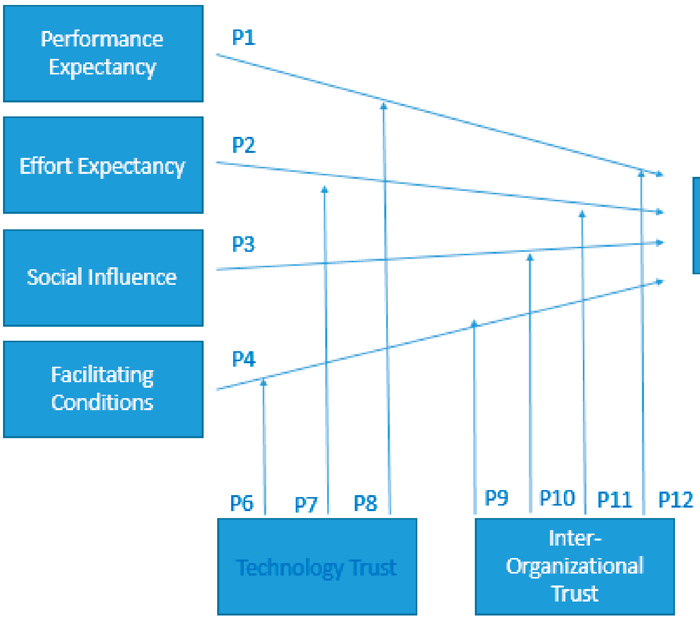

Figure 2. Conceptual Model and Research Propositions.

4.1. *Performance Expectancy*

Proposition 1. *Performance expectancy positively impacts the behavioral intention of using blockchain technology for supply chain traceability.*

Performance expectancy is the degree the usage of a new technology can provide consumers the expected benefits for performing specific activities [31]. It stands to reason that the more a user using a technology improves their performance, the intent to use it increases. Williams et al. [21] claim that performance expectancy and behavioral intention are the best predictors for using technology.

Bartlett, Julien, & Baines [32] demonstrate that increased transparency results in greater performance because participants were able to plan better due to greater visibility of their impact upon the supply chain. Blockchain offers a solution for a trusted single-source of distributed information with improved information accuracy and efficiencies that provides asset managers more opportunity to scale and deploy resources [33].

4.2. *Effort Expectancy*

Proposition 2. *Effort expectancy positively impacts the behavioral intention of using blockchain technology for supply chain traceability.*

Effort expectancy refers to a technology's ease of use. Individuals are less likely to use technology if it is sensed to be more difficult to use and require effort than existing methods. Effort Expectancy and Performance Expectancy are closely related; however, the former is more closely aligned with *efficiency* expectations and the latter with *effectiveness* [34]. Supply chain operations efficiency impacts an organization's competitiveness and is shaped by numerous factors. Information sharing methodologies such as vendor managed inventory (VMI) create efficient replenishment models without the need for traditional orders [35]. Similarly, blockchain enables the use of "smart contracts" that are based on user defined rules requiring little to no human intervention.

4.3. Social Influence

Proposition 3. *Social influence positively impacts behavioral intention to use blockchain technology for supply chain traceability.*

Social influence is defined as the extent an individual perceives important others believe the new system should be used. By their design, blockchain applications are "social" technologies. However, where there is increased normative pressure and a "critical mass" of users [36,37]—thus realizing increased network effects – the situation could lead to higher intentions to use.

4.4. Facilitating Conditions

Proposition 4. *Facilitating conditions (i.e., technical resources and organizational support) positively impact behavioral intention to use blockchain technology for supply chain traceability.*

Venkatesh et al. [20] indicate facilitating conditions are defined as extent end users thinks a firm's technical infrastructure supports system usage. The highly networked nature of blockchain applications necessitates the availability of technical resources to enable use; a lack of resources will negatively effect its use. Similarly, if organizational support for use of blockchain is lacking, individuals use systems that are supported within the organization.

4.5. Behavioral Intention and Use Behavior

Proposition 5. *Behavioral intention will positively influence the use of blockchain traceability applications.*

Social psychologists have broadly explored behavioral intentions and a user's conscientious intent to perform a future behavior [38]. Several of the models integrated into UTAUT support the relationship between behavioral intention and use [22,23,25]. Venkatesh & Davis [39] identify in their research that there is a continuing trend for organizations to evolve from hierarchical structures to more networked, autonomous teams.

4.6. Technology Trust

Proposition 6. *Trust in technology positively moderates the relationship between Performance Expectancy and Behavioral Intention.*

Proposition 7. *Trust in technology positively moderates the relationship between Effort Expectancy and Behavioral Intention.*

Proposition 8. *Trust in technology positively moderates the relationship between Facilitating Conditions and Behavioral Intention.*

Trust in technology is unique in that it delineates the relationship between human and computing technology. Trust in technology is not new to researchers of human-machine interactions (e.g., "trust in information", "accept the advice", etc.). Tseng and Fogg [40] contend that "like many aspects of human society, computers seem to be facing a credibility crisis", and "the cultural myth of the highly credible computer may soon be history". Technology credibility influences people's attitude toward such technology, which further influences their intention to use such technology. For example, if users perceive that blockchain technology is not secure, they will be reticent to use or will not use the technology. However, the more users exercise and learn about technology, the more experience and knowledge they have, and the more trustworthy the technology seems to them. Thatcher, McKnight, Baker, Arsal, & Roberts [41] identify a lack of trust in IT may lead users to cease using or investigating technology due to lack of confidence about reliability or performance; such beliefs make trust a vital factor to understanding end users intentions.

4.7. Inter-Organizational Trust

Proposition 9. *Inter-organizational Trust positively moderates the relationship between Performance Expectancy and Behavioral Intention.*

Proposition 10. *Inter-organizational Trust positively moderates the relationship between Effort Expectancy and Behavioral Intention.*

Proposition 11. *Inter-organizational Trust positively moderates the relationship between Social Influence and Behavioral Intention.*

Proposition 12. *Inter-organizational Trust positively moderates the relationship between Facilitating Conditions and Behavioral Intention.*

Inter-organizational trust refers to trust between institutions and is critical for technology acceptance and information sharing [42]. Members within a supply chain are reliant of on other members for components or their ability facilitate operations. Trust is particularly unique in supply chains as competitors may also be interdependent between each other. See Table 2.

Table 2. Summary of Propositions.

#	Proposition	Independent Variable	Moderator	Dependent Variable
1	**Proposition 1.** *Performance expectancy positively impacts the behavioral intention of using blockchain technology for supply chain traceability*	Performance Expectancy	N/A	Behavioral Intention
2	**Proposition 2.** *Effort expectancy positively impacts the behavioral intention of using blockchain technology for supply chain traceability*	Effort Expectancy	N/A	Behavioral Intention
3	**Proposition 3.** *Social influence positively impacts behavioral intention to use blockchain technology for supply chain traceability*	Social Influence	N/A	Behavioral Intention
4	**Proposition 4.** *Facilitating conditions (i.e., technical resources and organizational support) positively impact behavioral intention to use blockchain technology for supply chain traceability*	Facilitating Conditions	N/A	Behavioral Intention
5	**Proposition 5.** *Behavioral intention will positively influence the use of blockchain traceability applications*	Behavioral Intention	N/A	Use Behavior
6	**Proposition 6.** *Trust in technology positively moderates the relationship between Performance Expectancy and Behavioral Intention*	Performance Expectancy	Trust in Technology	Behavioral Intention
7	**Proposition 7.** *Trust in technology positively moderates the relationship between Effort Expectancy and Behavioral Intention*	Effort Expectancy	Trust in Technology	Behavioral Intention
8	**Proposition 8.** *Trust in technology positively moderates the relationship between Facilitating Conditions and Behavioral Intention*	Facilitating Conditions	Trust in Technology	Behavioral Intention
9	**Proposition 9.** *Inter-organizational Trust positively moderates the relationship between Performance Expectancy and Behavioral Intention*	Performance Expectancy	Inter-organizational Trust	Behavioral Intention
10	**Proposition 10.** *Inter-organizational Trust positively moderates the relationship between Effort Expectancy and Behavioral Intention*	Effort Expectancy	Inter-organizational Trust	Behavioral Intention
11	**Proposition 11.** *Inter-organizational Trust positively moderates the relationship between Social Influence and Behavioral Intention*	Social Influence	Inter-organizational Trust	Behavioral Intention
12	**Proposition 12.** *Inter-organizational Trust positively moderates the relationship between Facilitating Conditions and Behavioral Intention*	Facilitating Conditions	Inter-organizational Trust	Behavioral Intention

5. Implications and Conclusions

5.1. Limitations

There are limitations of the UTAUT theoretical framework that should be noted. UTAUT presupposes that the main driving factor in technology adoption is the systems' usefulness (i.e., extrinsic motivation). This is supported by preceding technology acceptance frameworks concerning the adoption of production systems. Stanciu [43] identified the hedonic component (i.e., intrinsic motivation) involved in people's decision making regarding technology adoption becomes increasingly more important and difficult to ignore, even for systems which were traditionally utilitarian in nature. UTAUT departs from a number of psychological constructs such as the users' evaluative processes with respect to safety, risk and security, need for connectedness, user self-objectification, users' perceived similarity with others, etc.—with respects of blockcahin technology adoption, trends such as social responsibility, conscientious consumerism, and similar concerns. Additionally, although UTAUT is a predictive model, it does not provide guidance for steps to foster technology adoption [34].

5.2. Future Research Agenda

This research was aimed at understanding the adoption of blockchain technologies for traceability applications by end users. However, it opens more research questions than it actually solves. For example, future research should explore the following research questions.

Does the type of product or service impact end user adoption of blockchain? For example, will industries like medicine and aviation, where products must meet very strict standards, be more impacted by blockchain? Also, will it be less impactful or demanded for component parts and commodities such as nails, grain, and lawnmowers?

How does blockchain impact intra-company synergies between functions such as manufacturing, marketing, and finance? So far blockchain has been focused on inter-company transactions, but similar to other logistics and supply chain functions, blockchain may apply to both internal and external integration.

How will the proliferation of the Internet of Things (IoT), a technology that can provide information inputs, and blockchain be integrated? Perhaps IoT will provide more inputs and blockchain, through applications like smart contracts, will provide more output. Such an integration model requires less reliance on human intervention.

How will non-technological external factors such as regulation, company culture, and social acceptance impact adoption? The list of possibilities here are extensive.

Who will lead demand for greater transparency to compel downstream adoption? This task could be led by large retailers, regulators, or consumers. Blockchain implementation in a supply chain requires the full cooperation of everyone involved—and that's a tall order.

How will a blockchain enabled supply chain operate in the context of traceability? A case study or conceptual process model of supply chains (including nodes and arcs) may be developed to better understand practitioner application of blockchain technology for traceability.

What other theoretical lenses, such as diffusion of innovations, can provide enhanced conceptualization. Theoretical lenses from other disciplines may also provide new insights.

What types of blockchain innovations should be developed in concert with supply chain partners? Similarly, are there blockchain applications that should be extended to the greater community such as applications of the sharing economy?

How will user react to new costs and risks, including potential streamlining of job functions due to increased efficiencies and perceived less need for auditing? Blockchain is a radical departure from existing transaction processes and its impacts to society and industry are unclear.

5.3. Implications for Practice

The demand for supply chain transparency will continue to evolve over the coming years. Consumer expectations of product origins will increase, especially for high value items such as collectibles, pharmaceuticals, and food items, and they will want firms to verify their claims. In reality, many firms—especially large multinationals—can have a multitude of suppliers, but no one corporate function for supply chain visibility or traceability. In the case of a garment manufacturer who identifies color variations, the outcome is relatively benign. However, in the case of pharmaceutical product recalls, knowing with certainty the source of raw materials can be significantly impactful.

Blockchain helps enable firms to evaluate and mitigate supply chain risks by providing a reliable means to track and trace product origins and processes. This is more important than ever as consumers are increasingly concerned about production practices relating to human rights, food integrity, and environmental sustainability. The possibilities of blockchain for practitioners are diverse and impactful, including applications such as traceability, security verification, secure transactions, and rapid processing via smart contracts. Each of these areas provides potential for firms to gain competitive advantages. Blockchain technology also offers an opportunity for new entrants to showcase the virtues of their supply chain. This can be a significant advantage over less-agile, larger and more established competitors. Leveraging the provenance of their products and/or services and having objective data to back up such claims can be a significant advantage.

5.4. Conclusions

This is the age of empowered customers who demand more information about the products they purchase, including supply sources and complete manufacturing history. Meeting this requirement is often either too difficult, not cost effective, or even impossible given traditional supply chain information technology; however, blockchain contains the possibility of addressing this challenge. This new technology provides a level of supply chain transparency that allows supply chain managers to obtain the information consumers are demanding and thus contribute to their companies' competitive advantages.

The development and implementation of novel technology does not guarantee that it will be used and otherwise succeed. A theoretical insight is required to better understand the underlying motivators and barriers that will lead companies, or discourage them, from adopting blockchain technologies for supply chain traceability. Previous work has pointed to the importance of behavioral intention and its antecedents in influencing technology use. This paper introduces the Unified Theory of Acceptance and Use of Technology to expand the explanation of end user technology acceptance for blockcahin traceability applications. This theory provides a robust conceptual framework to explain these relationships and support the development of blockchain tools. By doing so, this research introduces the behavioral theory as a lens to understand the adoption of blockchain in the supply chain. A conceptual model is theoretically derived as a potential framework for understanding the adoption of blockchain for supply chain traceability. The conceptual model is supported by researchable propositions and balanced with supply chain management implications and future research suggestions.

Acknowledgments: No external funding was needed for this research.

Author Contributions: The authors collaborated on all sections of the paper and both authors participated in all writing and revising.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Nakamoto, S. Bitcoin: A Peer-to-Peer Electronic Cash System. Available online: http://www.Bitcoin.org/bitcoin.pdf (accessed on 2 September 2017).

2. Earley, K. Supply Chain Transparency: Forging Better Relationships with Suppliers. Available online: https://www.theguardian.com/sustainable-business/supply-chain-transparency-relationships-suppliers (accessed on 2 September 2017).
3. Virtual Currencies and Beyond: Initial Considerations. Available online: https://www.imf.org/external/pubs/ft/sdn/2016/sdn1603.pdf (accessed on 5 September 2017).
4. Crosby, M.; Pattanayak, P.; Verma, S.; Kalyanaraman, V. Blockchain technology: Beyond bitcoin. *Appl. Innov.* **2016**, *2*, 6–10.
5. Iansiti, M.; Lakhani, K.R. The Truth about Blockchain. *Harv. Bus. Rev.* **2017**, *95*, 118–127.
6. Awaysheh, A.; Klassen, R.D. The Impact of Supply Chain Structure on the Use of Supplier Socially Responsible Practices. *Int. J. Oper. Prod. Manag.* **2010**, *30*, 1246–1268. [CrossRef]
7. Skilton, P.F.; Robinson, J.L. Traceability and normal accident theory: How does supply network complexity influence the traceability of adverse events? *J. Supply Chain Manag.* **2009**, *45*, 40–53. [CrossRef]
8. Markman, G.; Krause, D. Special topic forum on theory building surrounding sustainable supply chain management. *J. Supply Chain Manag.* **2014**, *50*. [CrossRef]
9. Mathieson, K. Predicting User Intentions: Comparing the Technology Acceptance Model with the Theory of Planned Behavior. *Inf. Syst. Res.* **1991**, *2*, 173–191. [CrossRef]
10. Flint, D.J.; Larsson, E.; Gammelgaard, B.; Mentzer, J.T. Logistics innovation: A customer value-oriented social process. *J. Bus. Logist.* **2005**, *26*, 113–147. [CrossRef]
11. Seebacher, S.; Schüritz, R. Blockchain Technology as an Enabler of Service Systems: A Structured Literature Review. In Proceedings of the International Conference on Exploring Services Science, Rome, Italy, 24–26 May 2017; pp. 12–23.
12. The Bitcoin Blockchain: The Magic and the Myths. Gartner, 2016. Available online: https://www.gartner.com/doc/3278917/bitcoin-blockchain-magic-myths (accessed on 6 September 2017).
13. Crowe, P. There Is a 'Game Changer' Technology on Wall Street and People Keep Confusing It with Bitcoin. Available online: http://www.businessinsider.com/what-is-blockchain-2016-3 (accessed on 7 September 2017).
14. Hofmann, E.; Rüsch, M. Industry 4.0 and the current status as well as future prospects on logistics. *Comput. Ind.* **2017**, *89*, 23–34. [CrossRef]
15. Lamming, R.C.; Caldwell, N.D.; Harrison, D.A.; Phillips, W. Transparency in supply relationships: Concept and practice. *J. Supply Chain Manag.* **2001**, *37*, 4. [CrossRef]
16. Duhiggjan, C.; Wingfield, N. Apple Lists Its Suppliers for 1st Time. Available online: http://www.nytimes.com/2012/01/14/technology/apple-releases-list-of-its-suppliers-for-the-first-time (accessed on 11 September 2017).
17. A Guide to Traceability—A Practical Approach to Advance Sustainability in Global Supply Chains. Available online: https://www.unglobalcompact.org/docs/issues_doc/supply_chain/Traceability/Guide_to_Traceability.pdf (accessed on 7 September 2017).
18. Provenance Has a Big Year Ahead Delivering Supply Chain Transparency with Bitcoin and Ethereum. International Business Times. Available online: http://www.ibtimes.co.uk/provenance-has-big-year-ahead-delivering-supply-chain-transparency-bitcoin-ethereum-1537237 (accessed on 13 September 2017).
19. Roberts, J.J. The Diamond Industry Is Obsessed with the Blockchain. Fortune. Available online: http://fortune.com/2017/09/12/diamond-blockchain-everledger/ (accessed on 13 September 2017).
20. Venkatesh, V.; Morris, M.G.; Davis, G.B.; Davis, F.D. User acceptance of information technology: Toward a unified view. *MIS Q.* **2003**, *27*, 425–478. [CrossRef]
21. Williams, M.D.; Rana, N.P.; Dwivedi, Y.K. The unified theory of acceptance and use of technology (UTAUT): A literature review. *J. Enterp. Inf. Manag.* **2015**, *28*, 443–488. [CrossRef]
22. Ajzen, I.; Fishbein, M. *Understanding Attitudes and Predicting Social Behavior*; Prentice-Hall: Englewood Cliffs, NJ, USA, 1980.
23. Davis, F.D. Perceived Usefulness, Perceived Ease of Use, and User Acceptance of Information Technology. *MIS Q.* **1989**, *13*, 319. [CrossRef]
24. Ajzen, I. The Theory of Planned Behavior. *Organ. Behav. Hum. Decis. Process.* **1991**, *50*, 179–211. [CrossRef]
25. Taylor, S.; Todd, P.A. Assessing IT Usage: The Role of Prior Experience. *MIS Q.* **1995**, *19*, 561–570. [CrossRef]
26. Thompson, R.L.; Higgins, C.A.; Howell, J.M. Personal Computing: Toward a Conceptual Model of Utilization. *MIS Q.* **1991**, *15*, 124–143. [CrossRef]
27. Rogers, E. *Diffusion of Innovations*; Free Press: New York, NY, USA, 1995.

28. Bandura, A. *Social Foundations of Thought and Action: A Social Cognitive Theory*; Prentice Hall: Englewood Cliffs, NJ, USA, 1986.
29. Davis, F.D.; Bagozzi, R.P.; Warshaw, P.R. Extrinsic and Intrinsic Motivation to Use Computers in the Workplace. *J. Appl. Soc. Psychol.* **1992**, *22*, 1111–1132. [CrossRef]
30. Lippert, S.K. Investigating postadoption utilization: An examination into the role of inter-organizational and technology trust. *IEEE Trans. Eng. Manag.* **2007**, *54*, 468–483. [CrossRef]
31. Huang, C.-Y.; Kao, Y.-S. Utaut2 based predictions of factors influencing the technology acceptance of phablets by DNP. *Math. Probl. Eng.* **2015**. [CrossRef]
32. Bartlett, P.A.; Julien, D.M.; Baines, T.S. Improving supply chain performance through improved visibility. *Int. J. Logist. Manag.* **2007**, *18*, 294–313. [CrossRef]
33. Swink, M.; Schoenherr, T. The Effects of Cross-Functional Integration on Profitability, Process Efficiency, and Asset Productivity. *J. Bus. Logist.* **2015**, *36*, 69–87. [CrossRef]
34. Brown, S.A.; Dennis, A.R.; Venkatesh, V. Predicting collaboration technology use: Integrating technology adoption and collaboration research. *J. Manag. Inf. Syst.* **2010**, *27*, 9–54. [CrossRef]
35. Småros, J.; Lehtonen, J.-M.; Appelqvist, P.; Holmström, J. The impact of increasing demand visibility on production and inventory control efficiency. *Int. J. Phys. Distrib. Logist. Manag.* **2003**, *33*, 336–354. [CrossRef]
36. Markus, M. Toward a critical mass theory of interactive media: Universal access, inter-dependence and diffusion. *Commun. Res.* **1987**, *14*, 491–511. [CrossRef]
37. Granovetter, M. Threshold models of collective behavior. *Am. J. Sociol.* **1978**, *83*, 1420–1443. [CrossRef]
38. Aarts, H.; Verplanken, B.; Van Knippenberg, A. Predicting behavior from actions in the past: Repeated decision making or a matter of habit? *J. Appl. Soc. Psychol.* **1998**, *28*, 1355–1374. [CrossRef]
39. Venkatesh, V.; Davis, F.D. A theoretical extension of the technology acceptance model: Four longitudinal field studies. *Manag. Sci.* **2000**, *46*, 186–204. [CrossRef]
40. Tseng, S.; Fogg, B.J. Credibility and Computing Technology. *Commun. ACM* **1999**, *42*, 39–44. [CrossRef]
41. Thatcher, J.B.; McKnight, D.H.; Baker, E.W.; Arsal, R.E.; Roberts, N.H. The role of trust in postadoption IT exploration: An empirical examination of knowledge management systems. *IEEE Trans. Eng. Manag.* **2011**, *58*, 56–70. [CrossRef]
42. Chae, B.; Yen, H.R.; Sheu, C. Information technology and supply chain collaboration: Moderating effects of existing relationships between partners. *IEEE Trans. Eng. Manag.* **2005**, *52*, 440–448. [CrossRef]
43. Stanciu, D. Are current models of technology acceptance explanatory enough? An analysis of potentially underexploited psychological correlates of technology acceptance. In Proceedings of the International Scientific Conference eLearning and Software for Education, Bucharest, Romania, 27–28 April 2017; Volume 2, p. 616.