Supply Chain Management: an International J

Blockchain Technology: Implications for operations and supply chain management

Journal:	*Supply Chain Management: an International Journal*
Manuscript ID	SCM-09-2018-0309.R2
Manuscript Type:	Original Manuscript
Keywords:	SCM practices, Technology, Supply-chain management, Operations management

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Abstract

Purpose: To encourage the study of blockchain technology from an Operations and Supply Chain Management (OSCM) perspective, identifying potential areas of application; and to provide an agenda for future research.

Approach: An explanation and analysis of blockchain technology is provided to identify implications for the field of OSCM.

Findings: The hype around the opportunities that digital ledger technologies offer is high. For OSCM, a myriad of ways in which blockchain could transform practice are identified, including: enhancing product safety and security; improving quality management; reducing illegal counterfeiting; improving sustainable supply chain management; advancing inventory management and replenishment; reducing the need for intermediaries; impacting new product design and development; and, reducing the cost of supply chain transactions. The immature state of practice and research surrounding blockchain means there is an opportunity for OSCM researchers to study the technology in its early stages and shape its adoption.

Research implications: The paper provides a platform for new research that addresses gaps in knowledge and advances the field of OSCM. A research agenda is developed around six key themes.

Practical implications: There are many opportunities for organisations to obtain an advantage by making use of blockchain technology ahead of the competition, enabling them to enhance their market position. But it is important that managers examine the characteristics of their products, services and supply chains to determine whether they need or would benefit sufficiently from the adoption of blockchain. Moreover, it is important that organisations build human capital expertise that allows them to develop, implement, and exploit applications of this technology to maximum reward.

Originality: The first paper in a leading international OSCM journal to analyse blockchain technology thereby complementing a recent article on digital supply chains that omitted blockchain.

Keywords: Blockchain technology; research agenda; operations and supply chain management.

Paper Type: Viewpoint

1. Introduction

In April 2018, Marks and Spencer (M&S) declared that: "From corned beef to fillet steak, every single piece of beef that M&S sells can be traced back to the farm and animal it came from" (M&S Press Release, 2018). They claimed to do this so the customer has more 'faith' or 'trust' in their products and brand, suggesting this is a key factor in a consumer's purchasing decision. This demonstrates the importance of complete end-to-end transparency and traceability in the supply chain, especially for products that are safety critical. Yet just two months later, in June of 2018, the provenance of products sold by other leading grocery supermarkets came under major scrutiny. Sainsbury's were accused of using pork in their own-brand vegetarian meatballs; and traces of turkey were found in a vegan macaroni ready-meal from Tesco's new "Wicked Kitchen" product line (Morley et al., 2018). While this may not be a threat to human life, there are obvious reasons why this would lead to public outrage and to a loss of brand value. Hence, five years on from the high-profile European horsemeat scandal (e.g. Czinkota et al., 2014), and despite stricter certification requirements and investments in transparency, the security of some supply chain goods remains as questionable as ever.

Blockchain – the technology behind the Bitcoin cryptocurrency – has been touted as having the potential to solve the problem of achieving end-to-end transparency. It is an increasingly popular networking technology for streamlining business processes that uses a peer-to-peer (P2P) network to verify and share data. It represents a decentralised environment for transactions, where all entries are recorded on a public or private ledger that is visible to users. A private blockchain, for example, can provide security, timeliness and transparency to all its users with clear potential applications in operations and supply chain management (OSCM) (Pilkington, 2016). Although M&S claim their full beef traceability is based on using DNA sampling, the use of distributed ledgers with the ability to record immutable data from farm to fork may prove to be an even more effective solution that can also avoid the problems recently experienced by their rivals, Sainsbury's and Tesco. Indeed, it has been argued that blockchain offers solutions to the myriad of challenges thrown up by complex supply networks at a time when agility, speed and transparency are crucial (Ganeriwalla et al., 2018).

Despite the potential of blockchain technology for the field of OSCM, it has thus far received extremely limited attention in the academic OSCM literature. In the wider literature, there is work emerging in fields such as computing and technology, for example, research that provides an analysis of the Bitcoin system and other applications of blockchain technology, including smart contracts (Yli-Huumo et al., 2016). To the best of our knowledge, no paper that focuses specifically on blockchain is yet to appear in a leading international OSCM journal despite its potential significance. Although a framework for future research on digital supply chains was recently provided by Büyüközkan and Göçer (2018), the authors failed to mention blockchain technology – focusing instead on robotics, cloud computing, the Internet of Things (IoT), nanotechnology, sensor technology and autonomous vehicles. Thus, there is an important gap in the OSCM literature to examine the opportunities and challenges that blockchain presents to the field of OSCM.

There are indeed many opportunities for OSCM research into blockchain, including into how it will address important OSCM challenges such as those related to sustainability and product counterfeiting, comparisons with other technological implementations, how its implementation will affect trust and change supply chain relationships, the eventual study of implementation successes (and failures) across supply chains, and so on. Such analyses will help to determine whether the current hype surrounding blockchain is justified and whether the applicability of the technology is universal or contingent on certain factors. Meanwhile, it must also be determined whether the theories most commonly employed in the OSCM literature to make sense of important phenomena suffice for blockchain research or if new theory is necessary. The purpose of this paper is therefore to:

1. Provide an overview of blockchain technology for an OSCM audience given the potential of the technology to contribute positively to the field, taking stock of what is currently known about blockchain technology in the broader, extant literature;
2. Suggest streams of OSCM research that may benefit from the study of blockchain technology; and,
3. Propose a future research agenda for OSCM scholars, identifying relevant research questions.

The remainder of this paper is organised as follows. Section 2 outlines blockchain and highlights applications of the technology outside of the OSCM field, including in the financial sector where blockchain has its origins. Section 3 then explains blockchain technology in more detail and introduces a technology adoption process that can be applied to blockchain and used to structure what follows in our paper. Section 4 then covers important topics from the OSCM literature related to blockchain technology adoption. This includes blockchain technology development for OSCM, the evaluation of the decision to adopt blockchain (and the historical lessons learned from other electronic SCM (e-SCM) technologies), incentivising blockchain adoption across the supply chain, trade-offs in blockchain technology adoption with other corporate drivers (e.g. economic and environmental considerations), the implementation of blockchain technology in complex supply networks, and research on supply chain relationships once blockchain technology has been integrated. Lastly in this section, the suitability of some of the theories typically used in OSCM research for studying these new phenomena are evaluated. Section 5 then provides an agenda for future research on blockchain organised around six key themes. We suggest that these themes are particularly ripe for further work, but this is not intended to be an exhaustive list of all opportunities. Finally, Section 6 provides conclusions, with a particular emphasis on the implications for practice.

2. Blockchain Technology

2.1 What is Blockchain Technology?

Blockchain is, essentially, a distributed database system that records transactional data or other information, secured by cryptography, and governed by a consensus mechanism (Swan, 2015). Developed in 2008 by Satoshi Nakamoto, the unknown person or people behind the bitcoin white paper, it is a data structure that combines data records, called blocks, in a chain. The chain is an electronically distributed ledger or list of entries that users or participants maintain via a network of computers. Specifically, blockchains use cryptography to process and verify transactions on the ledger. A fundamental advantage of this distributed system in a commercial context, where no single entity has control, is that it resolves problems of disclosure and accountability between individuals and institutions where the interests of the parties are not necessarily aligned. Data that is important to all parties can be updated in real time, removing the need for laborious, error-prone reconciliation processes with each party's internal records (Casey and Wong, 2017). It therefore provides each member of the network with far greater and timelier visibility of the activity occurring in the network. It can be a source of big data, which is of great benefit to organisations and supply chains, and therefore now receiving significant research attention from OSCM scholars (e.g. Kache and Seuring, 2017). The data encryption and coding in a blockchain improves transparency, efficiency and trust in information sharing (Misra, 2018).

There are four main facets or characteristics of a blockchain (Pattison, 2017). First, as it is designed to be *distributed and synchronised across networks*, it encourages businesses to share data and is therefore ideal for multi-organisational business networks, such as supply chains or financial consortia. Second, blockchains contain *smart contracts*, an agreement made between participants in advance and stored in the blockchain. A smart contract is a computer protocol intended to digitally facilitate, verify or enforce the negotiated terms of a contract – allowing for credible transactions without the need for third-party interventions as they are automated. These specific protocols can decide whether a specific operation, such as a given payment, should be permitted or not (Pilkington, 2016). Other than the payment itself, potentially via a cryptocurrency, smart contracts can also define functions and conditions, including the validation of assets in a range of transactions with non-monetary elements (Reyna et al., 2018). This gives confidence to the various actors in the network that everyone is 'playing by the rules'. Third, the blockchain is built using *P2P networks* whereby there must be agreement between all relevant parties that a transaction is valid, which serves to keep inaccurate or potentially fraudulent transactions out of the database. And fourth, *immutability of the data* means that agreed transactions are recorded and not altered. This provides provenance of assets, which means that for any asset it is possible to tell where it is, where it has been and what has happened throughout its lifetime.

There are both public (e.g. Bitcoin) and private (permissioned) blockchains. The main difference between the two is with regards to membership, i.e. who is allowed to participate in the network. A public blockchain is completely open, meaning anyone can join and participate in the network. The network typically has an incentivising mechanism to encourage more participants to join. Bitcoin is one of the largest public blockchain networks in production today. One of the drawbacks of a public blockchain is the substantial amount of computational power that is necessary to maintain a large-scale distributed ledger. More specifically, to achieve consensus, each node in the network must solve a complex, resource-intensive cryptographic problem called a "Proof of Work" (PoW) to ensure all nodes are synchronised. Alternatively, a Proof of Stake (PoS) or Proof of Authority (PoA) could be used, depending on the nature of the blockchain and its permission structure (Angrish et al., 2018). Meanwhile, private blockchains require an invitation and participants must be validated. Businesses (and supply chains) would normally set up a private, permissioned network rather than a public, open network (Pilkington, 2016). The access control mechanism can vary, for example: existing participants might decide future entrants based on a set of rules put in place by the network initiator; a regulatory authority could issue licenses for participation; or a consortium could make the decisions instead. Once an entity has joined the network, it will play a role in maintaining the blockchain in a decentralised manner.

2.2 Blockchain Technology in the Financial Sector

Unsurprisingly, the majority of applications of blockchain technology have been in the financial sector, and it is here that the technology has its origins. For example, it was developed to underpin bitcoin, the decentralised P2P digital cryptocurrency network. Bitcoin enables a multi-billion dollar global market of anonymous transactions without any governmental control. Hence, it has to deal with a number of regulatory issues involving national governments and financial institutions as transactions are made with no middle-men or intermediaries, such as banks. Each transaction is broadcasted to every node in the Bitcoin network and is recorded in a public ledger after verification (Crosby et al., 2016). Blockchain systems are also being used to manage bank guarantees, track financial transactions, combat fraud, and the use of smart contracts – which become active when network consensus agrees that conditions have been met, allowing for automated payments to be made – is increasing (Guo and Liang, 2016).

The technology however has potential beyond cash and currency as a distributed ledger of digital assets can be "programmed to record virtually everything of value and importance to humankind: birth and death certificates, marriage licenses, deeds and titles of ownership, educational degrees, financial accounts, medical procedures, insurance claims, votes, provenance of food, and anything else that can be expressed in code" (Tapscott and Tapscott, 2016: p. 7). Thus, there are opportunities for blockchain implementation elsewhere, as will be demonstrated in the remainder of this article.

2.3 Blockchain Technology in the Non-Financial Sector

Applications of blockchain are beginning to broaden out from the financial sector with the technology starting to change a number of industries. For example, in *healthcare*, blockchain is being used to track the progress of patients after they have been discharged from hospital, and electronic medical records in a blockchain have been used to enhance authentication, confidentiality and data sharing (Armstrong, 2018). Meanwhile, Forbes identified many more sectors that have or may benefit from blockchain (Marr, 2018). For example, with the *charity* sector under scrutiny, blockchain can provide greater transparency to charity donations and clearer links between charitable giving and project outcomes; and, in *property*, blockchains can track the complicated legal process that otherwise creates friction and expense in real estate transfers (Marr, 2018). *Retail* is using blockchain to enhance track and trace processes, sophisticated loyalty packages and even decentralised markets where goods and services are traded with no intermediaries (Chakrabarti and Chaudhuri, 2017). In *tourism*, the removal of intermediaries is being tested for car sharing and ride sharing in real time as well as to efficiently track and trade stocks of empty hotel rooms. In *media and entertainment*, blockchain systems can track intellectual property rights and payments to artists and allow for the creation of a record of ownership for artists' work (Dutra et al., 2018). In the *government* sector, blockchain can serve to provide greater identity verification and improve confidence in vote counting, thereby supporting the democratic process (Osgood, 2016). Finally, global examples of broad governmental interactions with blockchain include Dubai's aspiration to become the first blockchain-powered state, exploiting opportunities across health records, shipping and business registrations (Dutt D'Cunha, 2017); the creation of a new data centre that shifts public records onto the blockchain in Estonia (e-estonia, 2018); and the use of blockchain to manage public safety and transport applications in South Korea (Planning Korea, 2018).

There are many advocates of blockchain technology that have highlighted its benefits. For example, that blockchain promises to improve transparency, speed and responsiveness, that it is versatile, i.e. usable for any exchange, that it works on agreement with no disputes as everyone has a copy of the ledger, and that payments are triggered automatically. Yet, there are also sceptics of the technology spreading cynicism about its potential. Concerns have been raised about both the cost to switch to a blockchain system and about its environmental impact given that computational energy can be high (Gabison, 2016), especially in the case of large-scale public blockchains. Note however that the energy consumption of private blockchains tends to be much lower than public blockchains. For example, although bitcoin's network power consumption is impossible to measure due to its ever-shifting capacity, online reports have compared it to the energy demands of a state in the USA or to the demands of a small country (Yermac, 2017). Scepticism surrounds the investment needed to implement blockchain technology. For example, Hackius and Petersen (2017) found that logisticians struggle to access cases that properly demonstrate the benefits in order for them to justify the investment and time needed to implement blockchain. Finally, smart contracts have come under criticism. For example, they are only as good as the people who write them, so bad coding leads to problems – if there is a mistake in the underlying contract then blockchain's immutability may not prevail – and they ignore social contexts, which is particularly relevant to sustainable supply chain management, a key area that blockchain has been hyped to improve. Whereas data consensus is objectively easier to achieve, social consensus based on values and expectations is not so easy. Thus, further objective research is required into the value of blockchain considering the points raised by both advocates and critics of the technology. What now follows is a balanced appraisal of the use of blockchain technology development, adoption, implementation and integration in the field of OSCM, as will be later depicted in Figure 2, leading to a research agenda organised around six key themes that are later summarised in Table 3.

3. The Use of Blockchain Technology in the OSCM Field

Section 2 described a number of industries that are beginning to benefit from the introduction of blockchain technology. In addition, the application of blockchain to supply networks has the potential to transform the way in which firms do business. Figure 1 illustrates how a blockchain works specifically in the context of OSCM, where the block may contain data or trigger a smart contract. First, the development of the block is shown from requesting a new transaction through to the completed block being appended to the chain. Second, more detail is shown through a simple buyer-supplier example of what data might be recorded on the block at each stage and how the smart contract adds value to the process. Meanwhile, Table 1 demonstrates the suitability of blockchain for the discipline by relating the four main characteristics of blockchain from Section 2.1 to OSCM. The decentralised ledger, much like a stock ledger, acts as a single unified source of data, creating a clear audit trail and consistency across all vendors involved in, for example, manufacturing, assembly, supply and maintenance processes. Using blockchain, it may become possible for manufacturing companies to improve how quickly they trace problems with a specific product, component or material manufacturer (Angrish et al., 2018). Moreover, it helps to increase product safety and authenticity, improve service levels and decrease the cost of maintenance. Yet, to date, although there are pockets of activity, most applications are small scale – there are few documented examples of a blockchain being scaled up in the public domain, and very few manufacturing examples (Li et al., 2018).

[Take in Figure 1 and Table 1]

In real time, blockchains provide data to the network on the origins of materials, purchase orders, inventory levels, goods received, shipping manifests and invoices. Smart contracts match and verify this data against the agreement and trigger payment. It can autonomously trigger other transactions when key milestones are met, such as goods being issued (creating a shipment), pickup confirmed (activating a sensor) or proof of delivery (issuing an invoice). This takes place automatically without, for example, the use of spreadsheets or the manual raising of purchase orders or invoices. Smart contracts can also trigger automatic payment, which may or may not be in bitcoin or another cryptocurrency. Blockchain technologies promise to offer highly secure and immutable access to supply chain data because the databases are decentralised so that authenticity can be evaluated even when no single party is able to claim ownership of the supply chain's data (Kim and Laskowski, 2016). Using a blockchain can therefore enhance the velocity of the transaction and is potentially a reasonably low-cost option when combined with the IoT. Each transaction can be tracked and identified at any moment in time and, after the entry has been coded, it cannot be easily amended. A transaction is verified by consensus among the different members, and once it has been recorded it cannot easily be modified or deleted as the chain is comprised of blocks and modifying an existing block would require the agreement of the whole network (Crosby et al., 2016). Cryptographic PoW is required for new blocks to be accepted, although the anonymity of a blockchain in a supply network is unlikely to be desirable.

There are a number of potential applications of blockchain technology relevant to OSCM, as outlined in Table 2. These represent possible opportunities for blockchain implementation and are provided together with a pilot example of where it is being trialled in practice. Yet in all of these areas, challenges to implementation can be identified.

[Take in Table 2]

3.1 Technology Adoption Models and Implementation

A three-stage process of technology adoption, following the development of the technology, can be identified from the technology literature that is applicable to blockchain: (i) the evaluation of adoption, (ii) the implementation of technology, and (iii) integration (Grover & Goslar, 1993; Damanpour & Schneider, 2006). Thus far, most companies are at the development of technology, evaluation of adoption or initial implementation stage through pilots. There are few fully implemented and integrated applications of blockchain available to study meaning there are currently limits on the empirical studies that can be conducted. Figure 2 relates the development and adoption of blockchain technology to OSCM and identifies key themes for OSCM research within the technology adoption process. Five of these themes relate directly to the development, adoption, implementation and integration of technology while the sixth relates to the broader issue of scholarly research and theoretical understanding about blockchain in an OSCM context. These six themes are further explored in the following section and lead to a future research agenda (Section 5).

[Take in Figure 2]

4. Research Areas for Blockchain Technology in OSCM

4.1 Blockchain Technology Development for OSCM

e-SCM, where the internet facilitates the optimal coordination of links in the supply chain for better performance, provides adopters with several operational and strategic advantages

(Giménez and Lourenço, 2008). Examples of e-SCM include radio frequency identification (RFID), enterprise resource planning (ERP), customer relationship management (CRM), electronic data interchange (EDI), collaborative planning forecasting and replenishment (CPFR), and e-Procurement systems. While in the short-term, the broad operational goal of e-SCM is to increase productivity and reduce both inventory and cycle times, the long-term objective is more focused on the improvement and innovation of end-to-end processes between companies, their customers and suppliers (Rai et al., 2006; Yao et al., 2007). Beyond the functionality of the application, Lin (2014) explained that e-SCM relies heavily on socio-technical interactions (such as a shared database and joint decision-making) to permit the integration of otherwise fragmented, silo-oriented supply chain processes (Rai et al., 2006; Ke et al., 2009). Blockchain is arguably the latest in a long line of technologies that can be used to support e-SCM, and it is important to establish whether it is able to live up to the hype and be more effective than some of its predecessors. Büyüközkan and Göçer (2018) provided a review of digital supply chain technology but omitted blockchain from their work thereby demonstrating the lack of academic attention on this important phenomenon, even in the most recent literature.

Of the above e-SCM solutions, blockchain technology has arguably the most in common with RFID and ERP. RFID has attracted a lot of investigation in the OSCM literature as, like blockchain, it provides an end-to-end supply chain solution (Attaran, 2007; Thiesse et al., 2011; Papadopoulos et al., 2017) and track and trace capabilities. Further, both have been advocated as means of improving the transparency of supply chains and of addressing problems such as product counterfeiting (e.g. Staake et al., 2009; Cheung and Choi, 2011). But the impact of RFID on supply chains has, in some instances, been rather underwhelming, and implementations have been difficult. Meanwhile, the ability of ERP to provide a network solution is restricted as implementation is typically limited to the boundaries of the firm. Thus, it is important to consider how blockchain implementations can learn from firms' past experiences with other e-SCM technologies, especially RFID and ERP.

RFID was once a niche technology, arguably like blockchain is now, but it is currently the most widely used mainstream technology for identifying and tracking products throughout the supply chain. As is the case now for blockchain, some retailers were early adopters of RFID in a bid to gain competitive advantage and were therefore more committed to the transition to RFID than other, more reluctant adopters or non-adopters. Kim and Garrison (2010) investigated South Korean retailers to identify key organisational characteristics that positively drive the evaluation of RFID before adoption. Their results showed that organisational needs (ubiquity, job relevance and performance gaps), perceived factors (benefits and cost savings), and organisational readiness (financial resources and technological knowledge) have a significant influence on RFID evaluation, which in turns impacts upon adoption and integration success. Wamba et al. (2009) conducted an empirical evaluation of the factors that matter the most and least to organisations when considering an investment in RFID. Their results indicated that three factors – the benefits, top management commitment, and improved alignment – mattered the most to adopting organisations. For example, adopters are more concerned with potential strategic advantages including information visibility and competitive differentiation and less concerned with costs than non-adopters (Wamba et al., 2009). This is an interesting implication for the adoption of other new technology if cost is less of a concern whilst it also raises questions around incentives for users.

ERP systems are software used to coordinate information and manage company-wide business processes on a common database, of which shared management reporting tools are a part (Lee et al., 2011). They are limited in their ability to extend beyond the boundaries of a given organisation. Integrating blockchain technology into an existing ERP system promotes a collaborative platform by joining a decentralised one-rule-enforced blockchain network. Although ERP systems, like smart contracts, can also automatically compare documents and trigger payments for their business, blockchain extends this to the network level, providing visibility and automation across the supply chain (Li et al., 2018). It is still possible to keep and record private data and protect business intelligence, but blockchain is an additive technology and thus a relatively cheap solution connecting individual ERP systems and keeping a shared system of records for inter-company transactions. It seems unlikely that blockchain will replace the need for internal ERP systems; thus, the focus should be on integration. Yet it cannot be said with certainty that blockchain can process the same number of transactions as current ERP systems as it has not yet proven its performance at scale. However, blockchain technology, when embedded in an application, simplifies the integration between parties and (due to its high level of security) reduces vulnerabilities (Li et al., 2018). Studies on integrating blockchain and ERP remain in their infancy, but by creating a single version of information, all systems, rather than talking to each other individually, are able to speak through a blockchain.

It is important that researchers and practitioners take note of experiences with RFID and ERP when evaluating blockchain technology. But it should also be noted that blockchains arguably offer more than RFID and ERP to the OSCM discipline due, for example, to P2P verification and smart contracts that enhance automation. Moreover, the technologies can be combined and are complementary – it does not have to be a case of choosing one over another (Reyna et al., 2018). For example, RFID can be used with blockchain for tracing and sensor activation within a network while ERP can be developed into a collaborative network platform, enabled by the blockchain. But the extent of this integration or how best to combine the technologies for maximum effect is yet to be explored in the literature.

4.2 Incentivising Blockchain Technology Adoption in the Supply Chain

At the current stage of technological maturity, it is mostly large global firms such as Unilever, Walmart and Sainsbury's that are trialling the use of blockchain technology to improve the transparency (and sustainability) of their supply chains with expected financial rewards to follow (edie, 2017). Given that firms like Unilever have committed to sourcing 100% of their raw agricultural materials in a sustainable manner, blockchain represents an important development. It is a means of building fully collaborative ecosystems and of moving towards meeting the United Nations' sustainable development goals. Technology developers on the market helping with this include Provenance, Landmapp, FOCAFET Foundation and Halotrade. Meanwhile, the Department for International Development, Sappi, Barclays, BNP Paribas, Standard Chartered and universities such as the University of Cambridge Institute for Sustainability Leadership and Tsinghua University in China are also active implementation partners.

The initial focus of empirical research into blockchain adoption is likely to be on large organisations. These firms will have greater resources, greater volumes of transactions, may have more geographically dispersed operations, more supply chain partners and/or more information to manage than smaller organisations. It is therefore arguably these firms that are most likely to adopt technological solutions that improve operational efficiency and lower their costs (Patterson et al., 2003). But the impact on small organisations should also not be overlooked as, for end-to-end transparency, they must play their part within the network and focal firms must consider how best to introduce this technology to small and medium sized enterprises in their network, how to incentivise them to engage with adoption, how to share or distribute the costs of implementation, and so on. Research into how companies are obtaining buy-in from other actors in their supply chains is therefore needed. There may be an expectation that preferential financing, subsidies and tax incentives will be targeted at organisations that can verify their claims about transparency and sustainability, as has been previously seen for carbon financing (Antle and Diagana, 2003; Sarkar and Singh, 2010). Hence, blockchain implementation may become a route to realising the benefits and obtaining finance. However, research into these potential gains is also scarce in an OSCM context.

4.3 Blockchain and Other Organisational Trade-offs

The uncertainty surrounding the success of implementing blockchain technology in OSCM practices means that its adoption will carry a risk to the firm – the adoption of the technology may not pay off. Further, there may be trade-offs with other corporate objectives thereby calling into question decisions made on the allocation of resources. For example, if a food retailer intends to reduce their digital waste or energy usage, implementing a blockchain, however small, would see this waste or usage increase. These drawbacks, combined with the financial costs, need to be compared with the benefits, such as improved traceability of food temperatures through the logistics process monitored by RFID sensors and authenticated through blockchain technology. With few best practice firms to imitate, combined with scepticism on the benefits of the technology and no universal agreement or standards on the application of the technology across the network, firms are understandably cautious on the effects that blockchain might have on other aspects (Yli-Huumo et al., 2016; Hackius and Peterson, 2017: Kshetri, 2018).

Given the above, many research gaps exist for studying the opportunity costs of implementing blockchain in OSCM. First, trade-offs could be recognised and investigated by scholars via the usual cost-benefit approach, critically questioning the gains to be made by implementing blockchain given the financial investment that is required. Second, sustainability trade-offs should also be recognised and investigated. Research on measuring financial performance when resources have been spent on sustainability initiatives has been proven and published (Rao and Holt, 2005; Green et al., 2012). Similar studies are required to investigate the cost-benefit analyses of the environmental and social gains of using blockchain technology against the financial outlay associated with implementation and business-as-usual. Finally, aside from the financial sector, e.g. cryptocurrency, research on products and services that best lend themselves to a blockchain implementation and are thus worth the trade-off, are scarce. Hence, there is an opportunity for research that determines the characteristics of products, services and supply chains that would see payback from implementation. For example, Table 1 previously identified the characteristics of a blockchain and how they might benefit the practice of OSCM (by being distributed and synchronised P2P networks, using smart contracts, and the immutability of data) and further work could advise managers on how to exploit these opportunities. Meanwhile, Table 2 identified areas where blockchain may add value to OSCM.

The trade-offs associated with investing in blockchain technology for each of these areas – including quality, inventory, counterfeiting, and new product development – are also useful avenues for further research.

4.4 The Implementation of Blockchain Technology in Complex Supply Networks

Many studies have been conducted into the complexities and challenges associated with multi-tier, complex global supply networks. As organisations have increasingly outsourced to low-wage economies around the world, this has been an important focus for OSCM researchers. The disadvantage of sourcing from low-wage and low cost production countries is the physical distance horizon resulting in only partially effective behavioural monitoring and control mechanisms (Awaysheh and Klassen, 2010). Thus, research has investigated supply chain transparency and related issues such as regarding the origins of materials, including illicit subcontracting and product counterfeiting (e.g. Lima et al., 2018; Machado et al., 2018), concerns over modern slavery (e.g. Gold et al., 2015; New, 2015; Stevenson and Cole, 2018), and how to extend sustainable practices and governance upstream in supply chains (e.g. Grimm et al., 2016; Wilhelm et al., 2016).

As an example, complex multi-tier sub-supplier networks have, in some cases, been costly to firms claiming to pursue a socially sustainable agenda when unethical practices have been uncovered in their supply chains, with damaging consequences for sales, shareholder wealth and reputation (Czinkota et al., 2014). Thus, the actions of supply chain partners can have a significant effect on focal firms; and this, coupled with stakeholder pressures, means large focal organisations are taking more interest in and responsibility for the actions of their suppliers (Hartmann and Moeller, 2014; Touboulic et al., 2014). Hence, not only their own actions, but also the actions of suppliers, can directly impact, both positively and negatively, the reputation and performance of a firm. Improved transparency of the suppliers' behaviour can therefore help to build more sustainable business relationships between parties in the supply chain (Leppelt et al., 2013).

Blockchain technology has been hyped as a solution to the sub-supplier transparency problem in multi-tier supply networks (Francisco and Swanson, 2018), and to related issues like product counterfeiting (e.g. Toyoda et al., 2017; Kshetri, 2018). The digital ledger blockchain technology solution provides visible, honest and immutable records of physical asset origins (Sultan et al., 2018), improving provenance and authentic logistics information. Blockchain can be used, for example, to trace the origin of a product thereby supporting work on counterfeiting, sustainability, product recalls, etc. Further, although complex supply networks are difficult to map, blockchain technology offers the opportunity to increase visibility, transparency and auditability using distributed ledger technologies to drive trust, openness, visibility and integrity. Blockchain can significantly increase transparency from the origins of a product, through the shipping process and ultimately to customer delivery. For firms at a high reputational risk – if it transpires their supply chains are unethical – or that they provide safety critical products thereby making complete end-to-end visibility crucial, there are boundless opportunities for digital ledger technologies, yet only a handful of companies are experimenting with blockchain implementation to date.

From the above it follows that blockchain has the potential to have a major impact on the OSCM field. As research suggests, if sustainable supply chain management is positively associated with higher levels of organisational performance (e.g. Reuter et al., 2010; Ageron et al., 2012) then pursuing innovative technologies that enhance this is appealing to large corporate firms as it will allow them to digitalise their physical supply chains for better supply chain provenance. Yet the limited uptake of blockchain in practice to date means that empirical evidence to support these claims is lacking. There is thus an important gap in the literature to evaluate the impact of blockchain on improving the transparency of multi-tier networks, potentially working alongside organisations as they begin to adopt the technology. Investigation into the implementation challenges with blockchain technology, how they can be overcome and thus appropriate strategies for effective implementation across multiple tiers of the supply chain is also needed. The impact of blockchain adoption and implementation is explored further in the next subsection.

4.5 Blockchain and its Effect on Supply Chain Relationships

The uncertainty involved in decision-making and partnering between supply chain members can be reduced by building trust, because the trusting partner has confidence that the other party can be relied upon (Morgan and Hunt, 1994). Trust also facilitates a greater mutuality in goal setting and tackling issues (Sahay, 2003), such as in the context of sustainability; and trust in supply chain members, as a cooperative governance mechanism, can be utilised to create value (Cuevas et al., 2015). The link between trust and the use of blockchain technology however is not clear and therefore in need of further scrutiny by researchers. Blockchain has the potential to create end-to-end transparency, which gives firms confidence in their supply chains; but does this mean that firms trust each other or that they did not and that they therefore needed to adopt blockchain as a response, for example, to opportunistic behaviour?

There are two schools of thought on the link between blockchain and trust, as briefly outlined in the following two subsections before Section 4.6 suggests appropriate theory frames for studying blockchain in an OSCM context.

4.5.1 Blockchain Technology and Trustlessness

One school of thought is that blockchain removes the need for trust from the network because the data cannot be forged. Blockchain has in fact been described as a 'trustless' system (Swan, 2015; Glaser, 2017) because there is no reliance on the trustworthiness of a counterpart to ensure the (smart) contract is being met, as technology is used to ensure this is happening. Blockchain arguably enables the distribution of trust across the network because it does not require high levels of confidence in single authorities as a verified, immutable record of transactions is available and governed by the system itself (Zhu et al., 2019). In the past, it has been believed that an organisation's own information gives them a crucial competitive advantage and firms have had no desire to share it freely (Agrawal and Pak, 2001) whereas blockchain requires data access or the relationship will not be viable.

To further understand this argument, consider that the capability of blockchain technology within a supply network has been likened to working in a vertically integrated chain (Catalini and Gans, 2016). While using blockchain technology does not mean a supply chain is vertically integrated in the traditional sense of ownership, the information flows will be more fluid. Vertically integrated organisations, in a traditional sense, need to be willing to allow their partners to view internal systems and processes to build an end-to-end process and need to understand the implications of integration across the entire supply chain (Venkatraman and Henderson, 1998). Blockchain partners may need to consider the same. But whereas, in the past, organisations wishing to extend their processes have had to develop more trusting and collaborative relationships with their business partners, it might be argued that this will not be the case with blockchain. In fact, blockchain acts as the strongest type of contractual agreement and so agency mechanisms, which have been disappearing through trust (Cuevas et al., 2015), are more evident again. Trustlessness is an antithetical characteristic of a successful supply chain as it is generally accepted that a degree of trust enables a supply chain to prosper (e.g. Ireland and Webb, 2007). Thus, the controversy around 'trustlessness' and blockchains warrants in-depth investigation to resolve the debate, and such work could also serve to provide a more general contribution to the OSCM literature on supply chain trust, relationships and governance.

Zhu et al. (2019) have developed a Controllable Blockchain Data Management (CBDM) model, which introduces a specific node in the network system, referred to as a Trust Authority (TA) node. In their work, they use a blockchain for a trustworthy, transparent and traceable approach to recording each user's request, yet they also introduce a TA to monitor users' identities and behaviours. The latter however takes away from the benefits of the decentralised nature of a blockchain as the TA is introduced to facilitate blockchain data management, to monitor data and minimize risk, thereby reintroducing an intermediary process. Instead of continuing in this direction, it is argued that the original trusted interface of the P2P network should be further developed (Angrish et al., 2018) – so that the initial entries are validated (Hawlitschek et al., 2018), such as through PoA where participants are vetted and aware of each other's identity.

4.5.2 Blockchain as a Network of Trust

The other view is that blockchain is a network of trust because, in permissioned networks, users must be invited (and thus potentially screened) and the output of the blockchain can be completely trusted. It has been argued that it is transactions where trust is of high value that lend themselves to blockchain technology implementation (Ganeriwalla et al., 2018). Indeed, adapted from Ganeriwalla et al.'s (2018) work, Figure 3 posits that blockchains have little value where automation is unnecessary and trust is not beneficial. Where the value of trust is low but the value of automation is high, blockchain may be useful, but other (potentially lower cost) solutions may equally suffice for achieving automation. Where the value of trust is high but automation is unnecessary (low), there may be some benefits to employing a niche application of blockchain if the cost-benefit analysis is positive. But it is where trust and automation are both high in the supply network that blockchain network can really make a difference. Empirical investigation that validates (or otherwise) this matrix and establishes the industries and firms that fit in each quadrant could help to improve the adoption of blockchain in the right areas of OSCM.

[Take in Figure 3]

4.6 Theory for Studying Blockchain in an OSCM Context

Research into the application of blockchain needs to be expanded in OSCM as well as other disciplines, ideally developing theories that allow us to appropriately tackle the next technological wave (Markus, 2015). Following on from the above, it could be argued that blockchain challenges the theories deployed and developed to view supply chains built on strong relationships and trust. It is therefore important to consider which candidate theories most commonly employed in the OSCM may help to improve our understanding of this contemporary phenomenon and whether blockchain research expands these theories in any way – we provide a starting point for this but further exploration is required.

Take, for example, social capital theory (e.g. Nahapiet and Ghoshal, 1998). This has emerged as an important means of explaining supply chain performance (Bernardes, 2010), but it may have only limited utility in understanding a supply network employing a blockchain even if it is the network that makes the blockchain work. This is because, although organisations have recently looked to develop more trusting and collaborative relationships with their business partners in order to gain greater end-to-end visibility, this may no longer be necessary with blockchain, leading to undesirable consequences (Hawlitschek et al., 2018).

A blockchain alters the forces involved in market transactions, dramatically lowering transaction costs by extensively reducing the need for intermediaries (Torres de Oliveira, 2017). This will dramatically alter the current OSCM landscape and change traditional supply chain models, removing the middle man and creating even more agile and transparent supply chains. It prevents goal asymmetry and acts as the strongest type of contractual agreement, protecting against parties acting in their own self-interest. Thus, it might be argued that transaction cost economics (TCE) theory (Williamson, 1979) and agency theory (Eisenhardt, 1989) will experience a *renaissance*. Although they have been criticised for their fit with many supply chain relationships (Fehr and Falk, 2002; Wiseman et al., 2012; Cuevas et al., 2015), blockchain – and the view of it being a 'trustless' system – arguably takes us back to this transactional form of relationship. Thus, applying the view of trust and agency mechanisms as complementary (Poppo and Zenger, 2002) or as substitutable (Cao and Lumineau, 2015), e.g. transactional and relational approaches, may be useful. But first, a more in-depth investigation into how blockchain technology relates to and challenges existing theory on supply chains is needed. Treiblmaier (2018) considered four established economic theories (principal agent theory, transaction cost analysis, resource-based view, network theory) to initiate and stimulate an academic discussion on the potential impact of blockchain but the author also appealed for more research to be conducted.

5. A Research Agenda

Section 3 has related blockchain technology to a number of important topics in the OSCM literature, demonstrating its potential impact. Moreover, as there has been only limited attention on blockchain in the OSCM literature; there remains a lack of consensus around the value and limitations of the technology, which reflects the immature state of the literature. There is much scope for furthering our understanding of blockchain from an OSCM perspective and of developing applications of this technology in relation to important OSCM problems, e.g. concerning sustainability, transparency, counterfeiting, etc. As has been demonstrated in the foregoing, blockchain also raises important questions around the value of trust in supply chains and around the most appropriate theory frames for studying supply chain phenomena.

Section 3 also identified potential avenues for further research into blockchain in an OSCM context. Yet, blockchain also remains an emerging phenomenon in practice, currently limited to only a few high profile examples, which affects the type of research that can be undertaken at present. For example, it is perhaps too early to conduct a large-scale survey of the impact of blockchain technology on supply chains; but engaged approaches, such as via action research, could be adopted to develop a richer understanding of how organisations adopt blockchain and begin to integrate it into their operations and supply chains. There is thus an opportunity for OSCM researchers to study blockchain in the initial stages and shape its adoption in practice.

We suggest six key themes for OSCM research into blockchains, as detailed in Table 3, with a mixture of empirical methodologies suitable for examining the phenomenon;

1. Blockchain technology development for OSCM;
2. Incentivising blockchain technology adoption in the supply chain;
3. Trade-off considerations affecting the adoption of blockchain technology;
4. Blockchain technology implementation in complex supply networks;
5. Supply chain relationships; and,
6. Theory application and development for blockchain.

[Take in Table 3]

6. Conclusions

Blockchain has been flaunted as the latest solution to the problem of achieving end-to-end transparency in supply chains, which is a more important goal than ever before given concerns over provenance. Yet there is a dearth of literature that relates blockchain technology to OSCM. This paper therefore serves as a general call to arms for OSCM researchers to conduct more research into the opportunities that blockchain can bring to OSCM and complements the work of Büyüközkan and Göçer (2018) on digital supply chains, which neglected blockchain technology. The paper has identified key areas where blockchain technology could enhance OSCM practices, and it has developed a research agenda for scholars in the field. The main audience for this paper throughout has been researchers – with a future research agenda being presented – hence the paper now closes with the implications for managers.

6.1 Implications for Managers

As has been demonstrated in this paper, blockchain has the potential to transform the way in which organisations do business and act as a catalyst for new supply chain models. Although the technology has many potential applications, it remains in its infancy; therefore, there are many opportunities for organisations to obtain competitive advantages from making use of this technology sooner and better than the competition, changing their market positioning – but only if the conditions are right. The potential areas of application include OSCM, thus this article has implications for operations and supply chain managers. The challenge for these managers is to determine whether blockchain is needed in their firm and industry. For example, whether they should expect it to succeed where other solutions previously hyped as being able to revolutionise the supply chain – such as RFID – have arguably failed to live up to their billing. And, if it does apply, how they can take maximum advantage of the technology.

We have attempted to remain open-minded about the use of blockchain, acknowledging its potential whilst drawing attention to concerns and criticisms surrounding the technology – its immaturity, the lack of evidence to date, concerns that it may not always be necessary, etc. It is therefore important that managers examine the characteristics of their products and supply chains to determine whether they need blockchain. If, for example, products are safety critical, there is a risk of quality failures or of product counterfeiting leading to the potential for product recalls – such as in pharmaceuticals, automotives or food – then blockchain technology could give producers confidence in the origins of the products that they are distributing to users and consumers and offer complete traceability should something go wrong. Similarly, if the supply chain is extended and global, with multiple echelons, complex product flows, and many different suppliers then blockchain could be extremely powerful at managing the complex network of organisations and flows of parts and capital. Meanwhile, where social sustainability is a major concern and represents a significant reputational risk – such as in the low cost, labour-intensive fast fashion industry – blockchain technology could enable firms to extend visibility of their supply chains beyond tier one and respond, for example, to calls for greater transparency in the form of modern slavery legislation. In other scenarios, such as for short, local supply chains, it may be questioned whether the use of blockchain technology would be worthwhile given the investment cost required.

Where blockchain does appear to apply, it becomes important for organisations to develop the human capital expertise to develop, implement, and exploit applications of this technology and maximise its value. For example, whether the potential of blockchain is fulfilled will be affected by how firms make use of the technology and combine it with other technologies, or how they use the data generated from applications of blockchain to make better, more informed and responsive decisions. It is also important that the organisation has a suitable strategy for implementing blockchain technology across the supply chain, obtaining buy-in from key actors and with the support of a technology provider.

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Figure 1. How a Blockchain Works (with simplified example) adapted from IBM Blockchain (IBM, 2018)

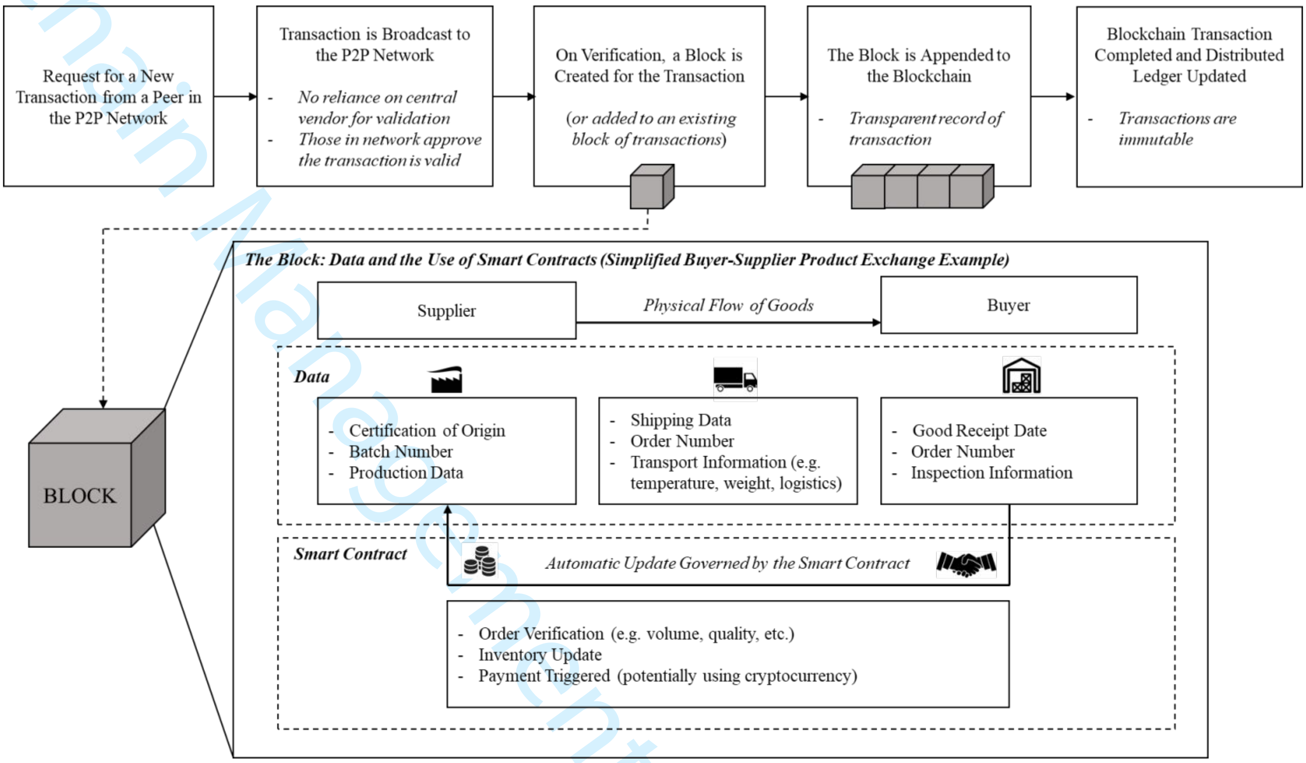

Table 1. The Relevance of the Four Key Blockchain Characteristics to OSCM

Characteristics of a Blockchain	Relevance to OSCM
Distributed and synchronised across networks	Global complex supply chains benefit from real time data maintained and accessed by each partner thereby increasing transparency and agility.
Use of smart contracts	Payments are made automatically when data matches, reducing checks, manual processes and human error.
Based on P2P networks	No central authority needed to manage the process, reducing governance requirements and reliance on a single actor.
Immutability of data	Forged paperwork will no longer be a risk and auditability is enhanced.

Table 2. The Potential Use of Blockchain in the Field of OSCM

Potential Uses for Blockchain Technology in OSCM	Explanation and *Pilot Examples*	Implementation Considerations
To enhance **product safety and security** by providing records of safety testing.	Security of the drug supply chain could be enhanced through the application of blockchain and smart contracts, e.g. by providing an immutable data ledger between manufacturers, wholesalers, pharmacies, hospitals and patients (Tseng et al., 2018). *Pfizer, AbbVie, Genentech, along with wholesalers AmerisourceBergen and McKesson are all involved in blockchain solutions to help speed up logistics, minimise discrepancies, create potential cost savings from streamlined processes, improve product visibility, and add transparency as products travel through the pharma supply chain to demonstrate compliance with the Drug Supply Chain Security Act.*	Blockchain is expected to succeed where RFID has not. Blockchain may be used to complement RFID capability.
To enhance **quality management** by providing visible and easily accessible information about batches, aiding recalls and improving service.	Paper-based freight documents are prone to loss, tampering, and fraud (Hackius and Petersen, 2017). *Maersk are piloting block chain, in conjunction with IBM, as the costs of shipping-related paperwork is between 15 and 50% of the physical costs of transport (Groenfeldt, 2017). Renault are trialling a digital car maintenance book that provides customers with new services in an ecosystem through blockchain (Renault, 2017)*	Blockchain has the potential to improve the quality of data and its visibility across the supply chain; however, a lack of standards and network speed are currently inhibitors. Standards are currently being generated by institutions such as the Blockchain in Transport Alliance (BiTA), a trucking industry consortium.
To reduce **illegal counterfeiting** by providing information of the origin of a product.	Blockchain can strengthen the transparency and traceability of goods in a supply network, thereby countering significant threats to licensing revenue and crew working conditions and safety (Visser and Hanich, 2017). Examples of goods being traced include food, pharmaceuticals and minerals. *Provenance (a UK based start-up) is working with businesses to keep track of the origins and journey of a product, e.g. where a product was made, how it moved across the globe, at what temperatures, etc.)* *Blockchain technology is being used to record data, collected on RFID and QR code tags, to manage the flow of tuna from the sea to plate for a pilot scheme being orchestrated by the World Wildlife Fund (WWF) in Australia, Fiji and New Zealand.*	Where IoT can be used, devices must be provided and funded. It may not be reasonable to expect the poorest suppliers to be able to afford this. Even M&S and Primark have only mapped to the 1st tier supplier stage, so full roll-out across the network will raise challenges.
Improve and automate contracts and reduce the need to develop trustworthy **supply chain relationships.**	Blockchain is an emerging technology for managing food safety based on decentralised and transactional data sharing across a network which does not require trusted participants (Tian, 2017). The complexity of manufacturing ecosystems and the lack of visibility of activities across multiple tiers, as demonstrated by on-going food scares across the globe, requires the development of trust in new ways through blockchains and smart contracts (Ganeriwalla et al., 2018).	Automating penalties for failing to abide by contractual obligations through smart contracts could lead to commercial issues and the dilution of relational trust. As organisations move their trading model from individuals to rely on the legal system

	Kouvala Innovation are attempting to use blockchain and RFID to communicate business need to move goods from point A to point B by a certain date. Blockchain technology assists with the bidding for the right to move that load. The business is automatically awarded to the carrier that best meets a shipper's price and service needs using smart contracts. Then, as the move progresses, the blockchain would continue to track the shipment.	(and smart contracts) they may have to depend on algorithms that they have not developed or fully understand.
Improve **inventory management.**	Inventory management challenges in shipping is reflected through overbooking of containers or customer "no-shows" of cargo to be shipped. These practices could be eliminated using smart contracts (Cottrill, 2018). *The New York Shipping Exchange in conjunction with businesses such as GE and Maersk Line are piloting the use of smart contracts and blockchain to alter these practices.*	Permissioned blockchain can support the implementation as all parties learn within the same closed network.
To reduce the need for **intermediaries** thereby reducing the complexity of the supply chain.	International purchasing offices/ international procurement organisations will no longer be needed when smart contracts can reliably perform their role. *NGOs such as Fairtrade will arguably no longer be needed to certify goods as the blockchain can do this.*	Intermediaries that add value outside of general functions such as logistics (e.g. knowledge development in sustainability) may also lose their position in the network.
To accelerate work on **design and new product development** by improving efficiency and delivering greater transparency between teams.	Blockchain has allowed the development of new insurance products such as peer-to-peer insurance, smart underwriting and contracts managed by computer systems automatically, e.g. to automatically make payments to policyholders when a triggering event occurs. *AIG and Standard Chartered have created new multinational insurance policies using blockchain.*	Internal process requirements such as recruiting suitable talent to ensure learning is developed as the technology matures is a challenge.
To revolutionise **IT in OM** by boosting access to tools and new practices, such as smart manufacturing.	Blockchains provide the basis for an open manufacturing system that shares information with customers as well as knowledge on how to handle the information shared between other enterprises in the supply chain (Li et al., 2018), beyond ERP systems. Blockchain and the IoT ecosystem are providing a trusted sharing data service, where information is both reliable and traceable (Reyna et al., 2018). *The Soil Association in the UK is piloting blockchain along with barcodes and QR tags to provide provenance for organic bacon from farm to fork supporting data sharing between producers, distributors, retailers and customers (CIPS, 2018)*	Blockchain can accelerate the development of the IoT ecosystem enabling operations to work with real-time data; however, recording all the interactions in the chain requires an increase in bandwidth, which is currently a significant blockchain challenge.
To reduce the cost of transactions through **automation**, enabling real	Through digitisation, the costs of many forms of transactions have been lowered such that they are close to zero. The introduction of blockchain supports digitisation through costless verification (Catalini and Gans, 2018).	Other priorities may exist and compete with blockchain implementation. For example, for the UK customs agency, the installation of a new customs declaration system ahead of

time auditing via time-stamping.	*BiTA is developing industry standards to enable greater visibility of activities within the supply chain, thereby reducing waste and costs. BiTA expects to have some hard metrics on the benefits of implementation in 2019 (CIPS, 2018).* *Business West, which issues provenance certificates for goods, is using blockchain to reduce customs checking (Martin, 2018).*	Brexit is more of a priority than establishing the customs system as a blockchain.

Figure 2. Blockchain Technology Development, Adoption, Implementation and Integration Leading to Six Themes for OSCM

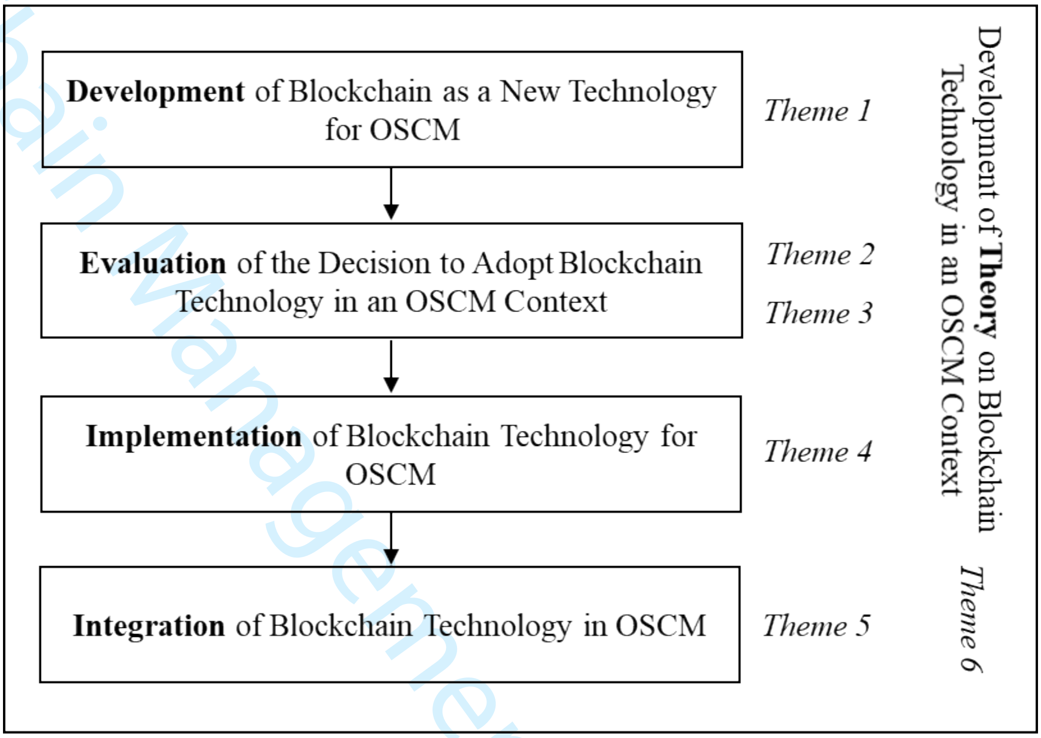

Figure 3. Value of Trust and Automation Matrix for Blockchain (adapted from Ganeriwalla et al., 2018 [Boston Consulting Group Analysis])

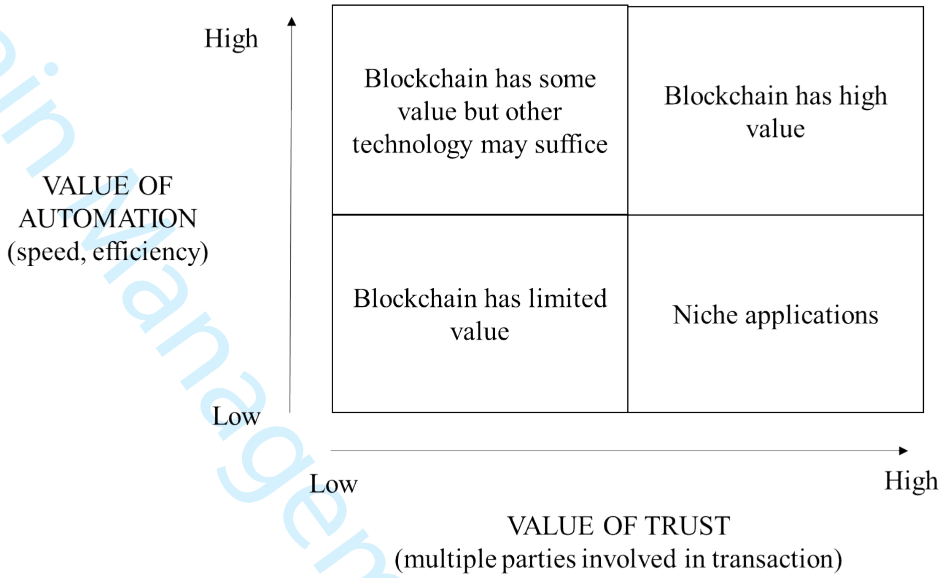

Table 3. Six Key Areas for Future Research with Proposed Research Questions

	Theme	Gap	Example Research Questions
1	Blockchain technology development for OSCM	Lack of comparison with other OSCM successful or unsuccessful technologies	*If blockchain technology has many of the same characteristics as RFID, how will it succeed where RFID has arguably failed to live up to the original hype? Further, how does the introduction of blockchain technology fundamentally change supply chains, for example, by linking internal ERP systems?*
2	Incentivising blockchain technology adoption in the supply chain	Lack of empirical evidence to show how companies are obtaining buy-in across the supply chain and who is bearing the financial burden of the implementation	*How can firms incentivise suppliers and other partners in the wider network to introduce block chain technology in order to achieve end-to-end transparency? Further, who should pay for the introduction of block chain technology in supply chains?*
3	Trade-off considerations affecting the adoption of blockchain technology	There is debate on the advantages and disadvantages of implementing blockchain technology but with no universal agreement	*What are the trade-offs involved in deciding whether to implement blockchain into the supply chain, including between:* - *The economic benefits and environmental energy usage?* - *The economic gains and costs of implementation?* - *The economic, environmental and social dimensions of the triple bottom line?* *Further, what characteristics of products, services and supply chains affect whether implementing blockchain is necessary or would payback?*
4	Implementation of blockchain in complex supply networks	Lack of studies explaining or evaluating OSCM applications of blockchain technology	*What are the implementation challenges with block chain technology, and how can they be overcome? Further, how can block chain technology be effectively implemented across multiple tiers of the supply chain?*
5	Supply chain relationships (incl. trust and governance)	Work on supply chain trust and governance mechanisms in supply chains remains ongoing and would be complemented by a blockchain perspective	*How does block chain technology impact the relationships between buyers, suppliers and other actors in supply chains? Further, how does the introduction of blockchain technology affect trust and governance in supply chains?*
6	Theory application and development for blockchain	Lack of theory associated with blockchain implementation (although other technology adoptions are well researched).	*How does the study of blockchain technology challenge existing theory on supply chain management?*