Improving social sustainability and reducing supply chain risks through blockchain implementation: role of outcome and behavioural mechanisms

CHAUDHURI, A., BHATIA, M.S., KAYIKCI, Yasanur <http://orcid.org/0000-0003-2406-3164>, FERNANDES, K.J. and FOSSO-WAMBA, S.

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Corresponding Author:	Atanu Chaudhuri Durham University Business School Durham, UNITED KINGDOM
Corresponding Author Secondary Information:	
Corresponding Author's Institution:	Durham University Business School
Corresponding Author's Secondary Institution:	
First Author:	Atanu Chaudhuri
First Author Secondary Information:	
Order of Authors:	Atanu Chaudhuri
	Manjot Singh Bhatia
	Yasanur Kayikci
	Kiran Jude Fernandes
	Samuel Fosso-Wamba
Order of Authors Secondary Information:	
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Atanu Chaudhuri[a,b]
atanu.chaudhuri@durham.ac.uk
Manjot Singh Bhatia[c]
MSBhatia@jgu.edu.in
Yasanur Kayikci[d]
yasanur@tau.edu.tr
Kiran J. Fernandes[a]
k.j.fernandes@durham.ac.uk
Samuel FossoWamba[e]
s.fosso-wamba@tbs-education.fr

a- Durham University Business School, UK
b- Department of Materials and Production, Aalborg University, Denmark
c- Jindal Global Business School, O.P. Jindal Global University, India
d- Turkish German University, Turkey
e- Toulouse Business School, France

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Abstract

The implementation of blockchain technology holds promise for improving social sustainability and minimising risks across the supply chain. A theory-driven analysis of how blockchain implementation affects social sustainability and minimises risks (outcomes) is missing in supply chain management literature. In particular, the role of technology service providers in meeting these outcomes is unknown. This research addresses these gaps by identifying the outcome-based and behavioural mechanisms needed to generate social sustainability and reduce risks through blockchain projects using agency theory as a theoretical lens. We conduct in-depth interviews with key stakeholders for four blockchain implementation projects to answer these questions. We identify that developing user-friendly applications, developing secure digital payment systems, providing support for suppliers and farmers and adapting to local conditions as the key outcome-based mechanisms. Educating and engaging with customers and building local relationships are found to be the key behavioural mechanisms needed to improve social sustainability and minimise risks using blockchain. Finally, we compare the cases and develop propositions.

Key words: blockchain; social sustainability; risk management; outcome and behavioural mechanisms; agency theory

1. Introduction

Currently, global supply chains are facing increasing challenges of unethical practices, fraud, counterfeit products, use of child labour and risks of low quality. Blockchain technology (BT) has been touted as having the potential to alleviate the above challenges. A prime example of BT application for ensuring social sustainability and minimising risk is the cobalt (Co) supply chain for electric vehicles. It is estimated that about 25% of cobalt mined from the Democratic Republic of the Congo uses child labour and, due to its high quality at source, is adulterated with low-quality cobalt from other countries. As a result of this adulteration, car manufacturers are unable to explicitly state that the cobalt used in their products has been responsibly sourced (Cassidy, 2020). Traceability using blockchain can ensure that fair practices are followed and help automotive manufacturers to minimise risks. Food supply chains are also particularly susceptible to risks. For example, leafy vegetables may suffer from salmonella outbreaks. In response, Walmart announced that it had asked suppliers of leafy green vegetables to begin implementing BT to trace their products back to farms (Hintze, 2019). Despite the potential of BT, it has only recently begun receiving attention in operations and supply chain management (SCM) literature (Cole et al., 2019).

Social sustainability is concerned with the human side of sustainability which addresses the issues related to quality of life and drives decision-makers to consider their decisions' potential social consequences (Mani et al., 2016). It is the human side of achieving sustainability objectives in supply chains to increase competitive advantage (Hussain et al., 2018). Research on social sustainability in supply chains is relatively new (Moxham & Kauppi, 2014; Nakamba et al., 2017). The social sustainability dimension has so far been emphasised mainly to satisfy legal requirements, human safety and legislative frameworks (Gualandris & Kalchschmidt, 2016; Sodhi & Tang, 2018), leaving the area of innovations for social sustainability largely unexplored (Orji et al., 2020).

Research on BT for social sustainability is also limited (Saberi et al., 2019; Lim et al., 2021). There is an extensive body of knowledge on supply chain risk management, but there is limited research on the application of digital technologies in this area (Ivanov et al., 2019). Katsaliaki et al. (2021) mentions that there is a need for case studies and surveys to test whether implementing BT decreases risks in terms of opportunistic behaviour among supply chain players. Kshetri et al. (2018) analysed the mechanisms by which BT can improve multiple supply chain performance measures such as cost, speed, dependability, flexibility, risk reduction and sustainability. Notably missing in the SCM literature is theory-driven analysis of real blockchain implementation case studies that focuses on social sustainability and risk minimisation. What is also unknown is the role of technology service providers in ensuring supply chain outcomes. Hence, we address the following questions in this paper:

1) What are the outcome-based and behavioural mechanisms needed to generate social sustainability and reduce risks through blockchain projects?
2) How do the role of these mechanisms vary in different projects?

The key contribution of this research lies in identifying the outcome and behaviour-based mechanisms needed for blockchain implementation to improve sustainability and reduce risks in supply chains. The results demonstrate how the relationships between mechanisms and outcomes vary for projects with a focus on social sustainability compared to those focusing on reduction of risks.

2. Literature review

2.1 An overview of BT

In the recent times, several technologies – primarily related to Industry 4.0 – are encouraging the development of new business models (Queiroz et al., 2019). BT has gained increased attention due to its potential ability to address several operational challenges in the manufacturing and service industries (Jabbar & Dani, 2020). BT, which started as a technology for financial services, has now expanded into sectors such as food, transport and logistics (Koh et al., 2020). A blockchain is “a digital, decentralized and distributed ledger in which transactions are logged and added in chronological order to create permanent and tamper-proof records.” (Treiblmaier, 2018). A distributed ledger is “a technological architecture designed for the clearing and settlement of digital asset trading and distributed computing without having the need for central intermediaries” (Yeoh, 2017). BT can “publicly validate, record, and distribute transactions in immutable, encrypted ledgers” (Swan, 2015). The core characteristics of BT are immutability, transparency, programmability, decentralisation, consensus and distributed trust (Treiblmaier, 2019). Immutability implies being unable to be changed. Transparency allows users read-only access to previous transactions (Treiblmaier, 2019). Immutability and transparency are both highly desirable if products need to be tracked across the supply chain. Decentralisation implies no central authority is needed to validate transactions between peers. Blockchain enables the distribution of trust such that it does not necessitate high levels of confidence in a single authority (Treiblmaier, 2019).

BT eliminates the need for any involvement of a third party for the management of financial transactions (Wang et al., 2019). BT aids in resolving issues related to trust and improves the transaction processes (Davidson et al., 2016). BT can also help firms to forecast more accurately, effectively manage resources and reduce inventory holding costs because of its ability to generate records (Kamble et al., 2019; Ren et al., 2020). However, the effective implementation of BT also has several challenges, such as a lack of organised eco-systems and data governance, concerns about privacy and high implementation costs (Kamble et al., 2019). The benefits and effectiveness of BT in most industrial sectors is yet to be ascertained (Koteska et al., 2017). Thus, many firms are uncertain about the appropriate use of BT (Sadouskaya, 2017).

2.2 BT implementation in supply chain

The integration of BT in supply chain will impact the entire supply chain network and improve supply chain operations (Queiroz & Wamba, 2019). BT can help deliver significant transformation of logistics and supply chain operations (Saberi et al., 2019; Choi, 2020). A major challenge in a supply chain is the tracing of products and data-management systems (Azzi et al., 2019). BT can help address the challenges associated with tracking of products and management of data. Tracking and tracing facilitate the prediction of hazardous events and preparations for managing such events.

The application of BT can help identify the activities of supply chain entities in real time (Kshetri, 2018). It can further improve supply chain operations, as all the transactions using BT are safe, efficient, traceable and transparent (Pilkington, 2016; Kshetri, 2018). The visibility and tracking provided by BT also help in cost reduction and in optimising the flow of information (Wu et al., 2017). The changes in the mechanisms of ensuring traceability of products with BT will improve networks' transparency – ultimately resulting in reduced product monitoring costs. For example, with improved traceability, the ability to combat fake drugs and counterfeiting will be significantly improved (Toyoda et al., 2017). BT can augment customers' trust, as it allows them to track the product journey (Fan et al., 2020). Thus, the traceability aspect of BT will prevent any fraud related to products in a supply chain (Chen, 2018). As a consequence, supply chains will improve in terms of economic and operational performance (Queiroz & Wamba, 2019). Implementation of BT also results in increased cooperation among supply chain entities (Aste et al., 2017), efficient management of supply and demand and reduction in inventory costs (Ivanov et al., 2019). For example, in an agricultural supply chain, the implementation of BT eliminates intermediate entities and ensures traceability and transparency – increasing efficiency and reducing risk (Yiannas, 2018). In food supply chains, provenance and information traceability improves the quality and safety of food. BT can contribute significantly to food supply chains by bringing about improvements in transparency, accountability and traceability (Kamble et al., 2020). BT has also been implemented in the food industry for ensuring prompt and fair payments to small farmers (Wang et al., 2019). BT also has potential benefits for improving information, financial and logistical flow in humanitarian operations (Rodríguez-Espíndola et al., 2020).

2.3 BT and supply chain risk management

Using BT, firms can mitigate supply chain risks at lower costs when compared to a traditional supply chain, in which firms tend to have higher stocks of inventory and excessive capacities due to expected disruptions (Ivanov et al., 2019). As BT helps to track and trace the complete movement of raw materials and products throughout the supply chain, it can help identify any potential risks, estimate the probability of disruption and any subsequent consequences.

Therefore, firms can plan mitigation steps and reduce the risk of disruption. For example, in the shipping industry, the visibility provided by BT can provide customs authorities with more information with which to analyse risk (Wang et al., 2019). This can eventually result in increased security and safety, and greater efficiency in border clearance procedures.

BT can also help in avoiding fraudulent transactions and security risks (Katsaliaki et al., 2021). There are several industries, such as luxury goods, wine and medicines, in which there are risks associated with the counterfeiting of products (Kshetri, 2018). According to World Health Organisation (WHO), there are 120,000 deaths per year in Africa due to fake malaria drugs (Wall, 2016). Thus, risk related to counterfeiting of products must be reduced. BT can help mitigate such risk through the tracking and tracing of raw materials and finished goods (Mackey & Nayyar, 2017; Wang et al., 2019), and makes it easy to detect any counterfeiting through authentication of data. Some manufacturing firms have also started to integrate BT in production processes (Xu et al., 2018) to eliminate the risks associated with counterfeit products in a supply chain. Due to greater transparency, BT can also encourage ethical behaviour and reduce risks related to unfair practices such as the exploitation of suppliers or the use of child labour in a supply chain.

2.4 Application of BT for social sustainability in the supply chain

Several firms have recently shown interest in adopting BT to improve sustainability in the supply chain (Bai & Sarkis, 2020). Sustainability is “development that meets the needs of the present without compromising the ability of future generations to meet their own needs” (WCED, 1987). Sustainability comprises of three well-known dimensions (economic, social and environmental) (Kamble et al., 2019). The concept of social sustainability arises from managers’ responsibility to handle social issues in a supply chain (New, 2004). Social sustainability is “an ethical code of conduct for human survival and outgrowth that needs to be accomplished in a mutually inclusive and prudent way” (Langhelle, 1999). In a supply chain, social sustainability refers to the issues related to processes and products which impact stakeholders (Klassen & Vereecke, 2012; Mani et al., 2016). Socially sustainable practices involve redesigning supply chains (Pagell & Wu, 2009) and helping organisations attain a sustained competitive advantage (Klassen & Vereecke, 2012).

BT helps to integrate social sustainability in the supply chain by making information immutable and ensuring transparency (Hastig & Sodhi, 2020; Saberi et al., 2019; Bai & Sarkis, 2020). Collaboration and knowledge-sharing in the blockchain can help to achieve social responsibility goals (Upadhyay et al., 2021). Indeed, the application of BT can aid in addressing several social sustainability concerns (Hastig & Sodhi, 2020; Saberi et al., 2019), such as tracking social conditions, which can cause concerns on safety and health (Adams et al., 2018) and detecting unethical suppliers and counterfeit products, as the information is recorded by authorised entities (Saberi et al., 2019). Customers are increasingly demanding information from firms on the origins of raw materials. In this regard, ethical and responsible sourcing has gained increased consideration in several organisations. Blockchain-enabled 'responsible sourcing' can also contribute to sustainability in supply chains (Young, 2018), as BT allows customers to trace the source of raw materials directly and subsequently track any modifications, thereby reducing any perceived risks (Yeung & Yee, 2012). This will help give customers complete assurance about the origin of raw materials and reduce financial risks associated with paying a premium for products made with unique materials (Montecchi et al., 2019). For example, in the coffee supply chain, NGOs and others that monitor fair-trade use "antiquated" techniques, while much superior and better results can be achieved with blockchain (Kshetri, 2018). However, few organisations have used BT to assure their customers about raw materials and reduce any associated risks. One example, Martine Jarlgaard (a fashion designer based in London), offered customers information about sourcing enabled by BT. Customers could track the authentication process of raw material (fleece) and the downstream processing steps. This process assured customers about the origin of raw materials and reduces any perceived financial risks (Montecchi et al., 2019). Peer Ledger uses BT for ensuring the responsible sourcing of gold (Peer Ledger, 2020). IBM has collaborated with RCS Global and Ford for the development of a blockchain platform to ensure responsible sourcing of cobalt.

BT can further contribute to socially sustainable operations by integrating the fulfilment of orders, distribution, payments, and human rights and environmental management functions (Korpela et al., 2017). BT can also aid smaller, financially and socially deprived firms and farmers by reducing asymmetry in information (Charlebois, 2018) and is expected to address other social issues, such as poverty and inequality (Kshetri, 2017).

2.5 Theoretical support for analysing BT implementation across the supply chain

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. Two parties have an agency relationship when they cooperate and engage in an association wherein one party (the principal) delegates decisions and/or work to another (an agent) to act on its behalf (Eisenhardt, 1989; Rungtusanatham et al., 2007).

The important assumptions underlying agency theory are that:

- potential goal conflicts exist between principals and agents;
- each party acts in self-interest;
- information asymmetry frequently exists between principals and agents;
- agents are more risk-averse than principals (Rungtusanatham et al., 2007).

Two potential problems may arise in agency relationships: an agency problem and a risk-sharing problem. An agency problem appears when agents' goals differ from principals' and it is difficult or expensive to verify whether agents have performed the delegated work appropriately. This problem also arises when it is difficult or expensive to verify that agents have the expertise they claim to have. A risk-sharing problem arises when principals and agents have different attitudes towards risk that cause disagreements about actions to be taken (Eisenhardt, 1989; Ross, 1973; Rungtusanatham et al., 2007).

To address these problems, agency theory prescribes two types of mechanisms: outcome-based and behaviour-based (Rungtusanatham et al., 2007). Outcome-based mechanisms emphasise results (Choi & Liker, 1995), while behaviour-based mechanisms emphasise tasks and activities in the agent's processes. Agency costs within principal-agent theory include the principal's monitoring expenses, bonding expenditures by the agent and residual loss (Jensen & Meckling, 1976). They occur as the principal wants to monitor, supervise and control the agent so that the latter acts in the best interest of the former. The principal has incomplete information regarding the agent's behaviour and therefore has to trust the agent to a certain extent. The outcome-based management mechanism emphasises results regardless of how the agents achieve them (Choi & Liker, 1995). The other management mechanism is behaviour-based. When this mechanism is used, principals can use behaviour controls to monitor agents' behaviours and efforts which otherwise are unknown to the principals. The behaviour-based management mechanism emphasises tasks and activities in agents' processes that lead to the agents' outcomes (Eisenhardt, 1989; Ekanayake, 2004).

In the context of BT implementation across supply chains, blockchain service providers play the roles of intermediates or agents to alleviate the risk-sharing problems faced by their customers. These service providers also have to deploy outcome and behaviour-based mechanisms to ensure that the desired outcomes are generated. Hence, we use the agency theory as the theoretical lens to identify and analyse the role of different outcome-based and behavioural mechanisms deployed by BT service providers to improve social sustainability and minimise risk across the supply chain.

2.6 Gaps in the literature

Despite a significant number of BT applications, there is still a dearth of studies on BT implementation applications in the supply chain (Queiroz et al., 2019; Fan et al., 2020). There is lot of speculation on the effect of implementing BT in a supply chain. However, the real understanding of the potential and outcomes of BT projects is limited (Wang et al., 2019). The adoption of BT in the supply chain is still relatively new, and most firms are yet to go beyond analyses, which can lead to adoption. Though recent surveys of supply chain professionals show that they are inclined towards the adoption of BT, the true potential of BT in supply chains is yet to be unlocked (Pournader et al., 2020). The critical success factors identified in the blockchain literature are data security, technological feasibility, operational model etc. (Hastig & Sodhi, 2020). Behnke and Janssen (2020) identify the boundary conditions needed for traceability in food supply chains using blockchain. Tönnissen and Teuteberg (2020) provide insights into how blockchain and (dis-)intermediation will change existing concepts in operations and SCM. But there is a lack of theory-driven analysis on how BT can improve social sustainability and minimise risk across the supply chain, and on the role of blockchain service providers. Theory-driven research allows for the development of propositions that can later be empirically tested. Thus, it enables researchers to systematically investigate blockchain and its potential implications from different theoretical standpoints (Treiblmaeier, 2018). Hence, using the lens of agency theory, we aim to identify the outcome-based and behavioural mechanisms that BT service providers can deploy to improve social sustainability and minimise risks across the supply chain.

3. Methodology

We used the multiple-case study method to answer our research questions. The unit of analysis for our study is the individual BT implementation project. The case study approach is appropriate for our investigation as there is limited research on actual BT implementation cases for improving social sustainability and for reducing risk across the supply chain (Yin, 2017). Finally, we seek to develop propositions that link new outcome-based and behavioural mechanisms deployed by BT service providers to improve social sustainability and reduce risk.

In this regard, we collected news articles on blockchain applications in SCM using Factiva. We used the following keywords: *blockchain and partnership OR Blockchain and supply chain OR Blockchain*. These keywords were used as the objective was to identify blockchain implementation projects in the supply chain. We covered BT projects between January 2017 and December 2019. A total of 43 news articles were obtained about specific blockchain implementation projects, out of which 23 cases were shortlisted based on whether they improve social sustainability, minimise risk across the supply chain or both. As mentioned in the news articles, the people in the shortlisted cases were searched on LinkedIn and contacted. The people who agreed to be interviewed were sent a brief note about the objectives of the research and the interview protocol before interviews took place. Finally, we received confirmation from people involved in four different blockchain implementation projects: two focused on improving social sustainability, and two focused on reducing risk across the supply chain. People from four companies agreed to be interviewed for this research. Representatives from a further 19 companies did not respond to our request.

In-depth, semi-structured interviews were conducted with key informants and other players in the chain, where possible. A total of 12 interviews were conducted. To supplement the interviews, additional material was collected from company websites and requested from the companies directly. Secondary news articles were also used. The additional material collected for iFinca included LinkedIn posts by the company and transcripts of two podcasts named 'Guaranteed Fresh', made by the CEO of iFinca. All these documents, along with the interview transcripts, formed the case document for iFinca, which was coded. For Plastic Bank, the additional material included LinkedIn posts and a document shared by Plastic Bank's CTO titled 'Plastic Bank's Successful Journey with Blockchain'. Additional material collected for BunkerTrace included an interview with the CEO which was published in a trade magazine, while those for AviationSpares included news articles and press releases shared by the company.

The interview transcripts were sent to the interviewees for validation. If needed, further clarifying questions were asked, which were responded to by the informants via email or through additional interviews. The first step in our data analysis involved an in-depth analysis of raw data (e.g. the case document including interview transcripts and the additional material we had collected). This analysis focused on reading every interview several times, each time marking phrases and passages related to the overarching research question. Two of the authors independently coded the interview documents and archival material. Wherever minor differences were observed in coding, the other authors collectively discussed those, and conclusions were reached. By coding the common words, phrases and terms, it was possible to identify first-order categories of codes, which expressed the respondents' views in their own words. In the second step, we discovered links within the first-order categories to create the second-order categories of mechanisms and their relationships to the outcomes by coding in NVivo. The findings of the study, the propositions developed and the frameworks were also validated by the interviewees. The details of the interviews conducted are provided in Table 1. Table 2 demonstrates how we ensured reliability and validity.

Table 1 Details of the interviews conducted

Case company	**Designation of the interviewee(s)**	**Duration of the interview**	**Industry sector**	**Outcome**
iFinca	CEO interview 1 CEO interview 2 CEO interview 3 Coffee farm owner Café owner	68 minutes 30 minutes 21 minutes 30 minutes 32 minutes	Coffee	Social sustainability
Plastic Bank	Co-founder 1 Co-founder 2	47 minutes 22 minutes	Recycled plastic	Social sustainability
BunkerTrace	Co-founder (interview 1) Co-founder (interview 2) Co-founder and technical architect	60 minutes 42 minutes 23 minutes	Bunker fuel for shipping	Risk management
AviationSpares (anonymised)	Senior R&D Manager 1 Senior R&D Manager 2	56 minutes 20 minutes	Aviation spare parts	Risk management and efficiency improvement

Table 2 Ensuring validity and reliability of the research

Quality of research design	**Case selection**	**Data collection**	**Data analysis**
Construct validity		Triangulated data: interviews, news articles, LinkedIn posts, company documents (Yin, 2017) Use of highly knowledgeable informants (Eisenhardt, 1989)	Establish and maintain a chain of evidence Use of case study protocol (Ellram, 1996; Yin, 2017) Draft reports viewed by key informants (Ellram, 1996)
Internal validity	Cases were chosen for different type of blockchain implementations across industries; cross-case analysis was conducted	Use of knowledgeable respondents, directly involved in the blockchain implementation projects	Pattern-matching among cases (Yin, 2017)
External validity	Multiple-case study approach (Ellram, 1996, Yin, 2017)	Gathering data on the case context	Consideration of case context (Eisenhardt, 1989)
Reliability	Established a chain of evidence including case study protocol and list of potential cases (Ellram, 1996; Yin, 2017)	Semi-structured interview guide included in case study protocol (Yin, 2017)	All interview transcripts analysed by interviewers (Yin, 2017)

4. Case profiles and background of blockchain implementation projects

4.1 Case profile and background of blockchain implementation projects by the case companies

4.1.1 iFinca

iFinca, a Colombia-based technology company, aims to streamline coffee sourcing and deliver greater value to farmers. It uses blockchain to verify purchases and to improve visibility across the coffee supply chain and uses two apps: one so that the end-customer can get to know the farmer and another for stakeholders to be able to have visibility of all the transactions. The CEO of iFinca met a coffee farmer and realised that the farmers were unable to negotiate prices, were disconnected from the rest of the supply chain and were price-takers.

Characteristics of the blockchain and the rationale for using it:

The first part of iFinca's blockchain platform is private and permissioned from the farm to the café. Only the buyer or seller of the coffee are able to access the platform and its information. At the café, some of the 160 data points become public – like the farmgate price and the identity of the farmer, as customers may like to have that kind of information.

> "*The first part is permissioned and private as people in the trade are concerned about what everybody can see. For example, disclosure of the fee which traders are charging –some people do not want that to share while others agree.*" CEO of iFinca

If an importer or a café owner wants to find ethically sourced coffee and ensure that the farmer has been paid a fair price, they would have previously had limited visibility of that. The coffee passes through many hands as it develops from harvested cherry to roasted bean, with different supply chain members adding value at each stage. The amount that the coffee's producers receive for their crop at the farm is known as its farmgate price. While many roasters share pricing information as part of their transparency efforts, most share the coffee's FOB (freight-on-board) price – which is paid to the exporter for coffee that is ready to ship. This FOB price does include what the farmer is paid, but also the coffee's milling, warehouse, transport and export costs.[1] Consumers presented with a high FOB price may assume that the producer takes home all or most of this amount. In reality, 40-80% of FOB (and even lower) is paid to the farmer. To address the above problems, iFinca developed the blockchain platform to connect the farmers:

> "*Blockchain protects transparency but doesn't provide it. It is a tool in the toolbox. We don't necessarily want blockchain. Our key motivation was how do we validate the information such as farmgate price? It is our responsibility that the data is correct as we are independent as we are not buying or selling coffee and blockchain helps us in doing that.*"- CEO of iFinca

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[1] https://www.ifinca.co/post/exploring-the-farm-gate-price

"*We are a unique, third entity party doing the validation. We don't want anybody at the government level buying or selling coffee to be the gatekeeper. Hence, a centralised system being controlled by the government will not work.*" CEO of iFinca

It started with Colombian coffee cluster. They started the pilot with one exporter, who bought from 350 farmers. iFinca kept producers informed by providing them with an integrated calculator to determine their coffee's parchment price. The calculator uses the yield factor – a formula that calculates how many parchment kilos are needed to produce a 70 kg sack of exportable green coffee. Thus, iFinca makes the farmgate price available to all buyers, and collects 160 datapoints covering everything in the chain. Buyers and sellers can scan anytime during the order and get a coffee chain ledger. The last buyer gets to see everything across the chain: growing process, ports, testing, roaster log etc. Inventory systems and carriers can also be added. It uses a QR code called Coffee Chain, which follows the coffee from farm to café. This is an encrypted QR code, and only the people involved with that coffee in the supply chain have access to all the data. All the data is protected with BT.

iFinca also developed a 'Meet the Farmer' app, through which customers at the café can scan another QR code with their smartphones.[2] A web page gives the customers information about the brand, the purchase date, the global market price on that day, the price paid to the farmer, plus information about the farm and the farmer, including the farm's name and size, farmer photos and certificates. Thus, iFinca has not eliminated any intermediary in the coffee supply chain but has played a key role in making the process transparent, ensuring fair price is paid to its farmers.

4.1.2 Plastic Bank

Plastic Bank builds ethical recycling eco-systems in coastal communities and reprocess the recycled plastic materials for reintroduction into the global manufacturing supply chain. The material is processed to produce what is known as Social Plastic®, which is then reintegrated into products and packaging. This creates a closed-loop supply chain while helping those who collect it.[3]

Both the co-founders grew up near Vancouver, Canada and depositing plastic bottles and being close to the water were part of their lives. One of the co-founders visited Manila, and witnessed

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[2] https://www.prnewswire.com/news-releases/democratizing-the-coffee-supply-chain-with-ifinca-300939497.html
[3] https://plasticbank.com/about/

a huge amount of plastic on the beach and in the water. This experience – coupled with the realisation that value can be generated by recycling plastic – motivated him to start Plastic Bank. Many global manufacturers have pledged to use recycled plastic, but the current world capacity for recycled plastic is only 10% of demand. Moreover, there is a high risk of unfair practices in such a disorganised supply chain.

Plastic Bank sets up plastic collection centres in different locations. Someone from the community collects the plastic and brings it to the locations, where they are sorted by type and colour. The plastic collection branch uses the Plastic Bank-developed application to load up the collector's account type, and the value is deposited in the collector's account so that it can be stored in digital savings or redeemed right away. When enough plastic is collected, it is transported to the processing partner, who registers the transaction using the application. The recycled plastic is converted to bales or flakes, or it is palletised. It is then transported to the customers' facilities to be used in production.

Characteristics of the blockchain and rationale for using it:

Plastic Bank uses a private blockchain with a customised token system in which it writes all the consensus rules in the system. It also uses a tokeniser reward system to reward plastic collectors by paying them above the market rate. The rationale for using blockchain can be explained using a quote of the co-founder:

> "*One of the biggest pains of doing things on paper is how can you trust that people actually got the right amount of money? The efficiencies that we've had is when our clients contribute funds to know that my plastic actually gave money back using blockchain just in real time and we can show that it is indeed recycled plastic and that this person received that exact amount. We indeed needed a secure way to have trusted data with full traceability throughout our supply chain. We also needed to digitise our reward programmes in a way that would offer savings accounts to vulnerable people in extremely low-tech regions and the answer was blockchain. I always stress the point that we are not a blockchain business. We are a business that happens to use blockchain to help solve a very specific problem. Our business would still exist without blockchain. However, for us, trust is the foundation of our promise. Trusted data, trusted impacts, and trusted users.*"

The system is open to auditing by the companies, which procure recycled plastic using the platform.

4.1.3 BunkerTrace

BunkerTrace is a joint venture that combines solutions and expertise from technology innovators BLOC and Forecast Technology Ltd. It provides visibility across the bunker fuel supply chain in the shipping industry. In September 2018, it completed the world's first digital end-to-end blockchain fuel transaction in the port of Rotterdam. BunkerTrace achieves both digital and physical traceability through a unique combination of technologies via a simple-to-use online application. Upstream in the supply chain, origin and data related to grade and specification of the fuel are recorded and embedded into a unique synthetic DNA tracer (tag).[4] This unique identifier is mixed with the fuel in small amounts and remains present as the fuel travels through the supply chain. By digitally tracking the physical tags throughout a fuel's journey, its system provides an immutable audit trail that can be easily verified with an on-board test before loading. This allows operators and managers to make informed decisions about whether to proceed with onboarding fuel.

One of the co-founders of the company had dealt with problems in his long shipping career, where he experienced engine damage because of poor quality fuel. Vessel owners thought they were buying a certain quality of fuel, and the vessel would go to a loading point, receive a paper certificate and load the fuel. But, sometimes, the vessel would break down in a few weeks' time, or there was severe damage to the engine. An investigation would reveal that the fuel was not of the quality ordered. Hundreds of such incidents happen in a year. Now, there is a new regulation that sulphur content should be less than 0.5% (this will go down to 0.05%), but violations are being reported. Much of the problem is associated with bunker barge operators. They take off residual poor fuel (which vessel owners do not want to keep) and regulations state that this can be discharged to the sea, but not before using an oil-water separator. Some unscrupulous bunker barge operators make deals with bunker suppliers, to take the residual fuel and mix it with the legitimate fuel. Similarly, vessels still dump this residue in the sea. It is difficult to identify the vessels that have been doing this.

BunkerTrace developed a synthetic DNA (an oligonucleotide) to mark the fuel, in order to address the above problems. By its nature, the oligonucleotide will gravitate to water. BunkerTrace, therefore, had to make it hydrophobic. Now, they can put the oligonucleotide in the oil refinery and the marked parcel of fuel can be delivered. When the fuel is delivered at the vessel, the captain and the first officer perform spot checks. They take a sample and analyse

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[4] https://www.ledgerinsights.com/bunkertrace-dna-blockchain-maritime-fuel-tracking/

it with an on-board computer which will tell them whether the fuel is of the quality they have ordered.

Characteristics of the blockchain and rationale for using it:

BunkerTrace uses a permissioned blockchain in which each user is given a key derived from a master key; each record is marked with the key. Users can only see what they have access to with that key, and everything is encrypted. The reason for using a permissioned system is explained by the company's technical architect:

> "*If you use the system across multiple shipping companies, they don't want to advertise what they are doing and there are some sensitivities around that. Hence, it has to be permissioned*."

The current system is "*based on little bits of paper- easily forgeable, lost, destroyed., it just didn't work*," said the co-founder of BunkerTrace. Samples of fuel are kept by the certifying authorities present in all loadings. How can one ascertain that the sample is actually from the fuel that is used in the ship? The rationale for using blockchain can be explained by the technical architect:

> "*You can deploy our synthetic DNA-based solution from management, deployment and delivery perspective but not from the enforcement perspective. Hence, practically, without blockchain, it does not work.*"

> "*If a regulatory authority has to develop a centralised system to monitor fuel quality on ships, they have to set up an enormous system to monitor the process connecting the physical and digital. A digital platform without the physical verification will just remain as digital pieces of paper. What actually happens on the ground and physically with the fuel can be messed with unless you do the marking, which is what we do, which together with blockchain ensures that nothing is tampered with*." Co-founder of BunkerTrace

4.1.4 AviationSpares

AviationSpares (name anonymised based on company request) is an online marketplace designed to bring buyers and sellers from the aerospace industry together intuitively and easily. For the platform, AviationSpares leverages blockchain to verify that quality documents and images match the specific part offered for sale. Used aerospace parts is a $5 billion industry with minimal online trade. Numerous emails and phone calls, along with paperwork, were used to close a transaction. The combination of high dollar transactions and aircraft safety explains why it has been difficult for buyers and sellers to move their transactions online. Unapproved aviation parts played a role in nearly two dozen crashes that killed seven and injured 18 since 2010 (Stock et al., 2016). The maintenance of an aircraft is a process that uses cumbersome databases. A commercial aircraft can be in use for up to 30 years and have five or six owners. Thus, tracking maintenance documents becomes an error-prone process, and is thus vulnerable to malpractice, violating procedures outlined in manuals and the Federal Aviation Regulations.

AviationSpares requires prices, product images and quality documents for a product to be listed for sale. This ensures high quality standards, with all purchased products required to have their associated quality documents intact. Equally, AviationSpares sets some of its protocols for the industry as it builds a record of an aerospace spare part via its serial number. All events related to that serial number are logged and recorded on-chain, so that any prospective buyer will have access to them. The blockchain-enabled platform provides pedigree information, i.e. history of the part's usage, images and quality documentation. It ensures that there can be no 'ghost' listings; only genuine sellers who are the rightful owners of the parts can participate – not intermediaries. The platform is also easy to use, and the buyer can check out efficiently.

Characteristics of the blockchain and rationale for using it:

It is a private, permissioned network on HyperLedger and, for each lifecycle event of the part, there is a separate smart contract. The network has to be permissioned so only eco-system players can access it. As the entire trace is available, the ledger is open for auditing. Blockchain adds credibility to the solution and lends value, and thus providing differentiation; it is an integral part of the offering. Blockchain adds a trust factor for the buyers. The solution can not only be used to help supply new parts after a piece has broken, or worn out, but also to crack down on poor quality or counterfeit parts entering the market.

5. Analysis

We asked specific questions related to the agency factors in the legacy supply chains before blockchain implementation and characterised the coffee, bunker fuel, recycled plastic and aviation spare parts from the agency factors.

5.1 Agency factors in the supply chains

5.1.1 Information asymmetry

Information asymmetry was either high or very high in all the legacy supply chains studied – thereby exacerbating the agency problem. For example, in the coffee supply chain, the buyers (i.e. the importers or roasters) only had visibility until the FOB price, while the farmers had no visibility of downstream prices. A quote by our interviewee summed up the degree of information asymmetry in the coffee supply chain:

> "*Farmer was not connected in receiving or giving information. Nobody could get the farmgate price before iFinca. Best they could get was the FOB at the loading port.*"

Similarly, in the bunker fuel supply chain the vessel owners had no visibility about the quality of fuel:

> "*Vessel owners thought they were buying certain quality of fuel. They go to a loading point, have a certificate in a piece of paper but the vessel breaks down in weeks or there is severe damage. They had no clue about the quality of fuel supplied.*"

5.1.2 Goal conflict

Goal conflicts were also high in all the supply chains, except in the aerospace spare parts supply chain, where the majority of suppliers had the same goal of delivering spare parts that meet all regulatory and safety requirements. The intermediaries in the coffee supply chain, such as the cooperative, the miller and the exporter had limited incentive to adequately pay farmers:

> "*Farmer was hoping that the cooperative was taking care of their interest and the cooperative was hoping miller or exporter were taking care of them. Still, the greed factor was there.*"

Goal conflicts were particularly high in the bunker fuel supply chain, where bunker barge operators prioritised profits over fair business practices:

> "*400+ incidents are arising out of one port this year of bunker fuel adulteration. At the end of the refining process, the residue left is dregs which are sometimes mixed with legitimate fuel. On many occasions, bunker barge owners will take the residual fuel and mix with the legitimate fuel. Similarly, some vessels were also still dumping in the sea.*"

5.1.3 Risk aversion of suppliers

Risk aversion in the bunker fuel supply chain was low, and suppliers were willing to take risks by engaging in unscrupulous practices. Risk aversion in the coffee supply chain is moderate, as intermediaries have some risk of losing business as well as the risk of disturbing their long-term relationships with farmers. But risk aversion in the recycled plastic supply chain was high, as employing child labour or not conducting appropriate sorting and grading could result in loss of business for recyclers.

5.1.4 Length of relationship

The length of the relationships between coffee farmers and intermediaries often runs for centuries and across generations, and the farmers had almost accepted that they would always be paid even lower than commodity prices. The length of the relationship between partners in the bunker fuel supply chain is low to moderate, depending on the vessel operators. Some of the vessel operators are concerned about quality and the environment and have long relationships with suppliers while in the other extreme, some of them always bought the cheapest fuel from different suppliers and neither cared for quality nor for the environment. In the recycled plastic supply chains, the length of the relationship between buyers and recyclers was short, as buyers can easily switch suppliers. The length of the relationship between buyers and suppliers in the aerospace supply chain varied depending on the parts' value. Thus, buyers would have long-term relationships for critical engine parts, but for commodity items, such relations would be short and transactional.

5.1.5 Task programmability

Task programmability refers to the extent that buyers can specify appropriate agent behaviour in advance. The parameters defined up front ease the task of measuring that behaviour (Eisenhardt, 1989). Such task programmability was easy for aerospace spares supply chain because of well-defined criteria and moderately difficult in the coffee and bunker fuel supply chain as quality depends on multiple factors, and not everything cannot be specified in advance. Thus, the coffee farmer has to take appropriate action depending on weather conditions etc., while the oil refiner will also try to optimise the process depending on the quality of the crude oil received. Similarly, task programmability in recycled plastic supply chain was also moderately difficult, as certain instructions (such as not mixing different types of plastic) can lack sufficient detail, as quality and source of the plastic available to be collected can vary widely.

5.1.6 Outcome measurability

Outcome measurability in the coffee supply chain is moderately difficult, as the quality was measurable, but not the prices paid to the farmers or practices in the farms – and there were chances that farmers were not paid according to the quality of the coffee they produced.

> "*When a farmer sells coffee that isn't fully processed (i.e. green), its cup profile is unknown. If this coffee is cupped after being sold and processed and receives a high cupping score, there are no guarantees that any bonus the exporter receives will be passed on to the producer.*"

Outcome measurability in the bunker fuel supply chain was very difficult, as it was difficult to ascertain the quality of the fuel on board the ship. Outcome measurability in the recycled plastic supply chain was also difficult, as it was difficult to measure the quality at collection and across the recycling processes. Outcome measurability in the aerospace spares supply chain was relatively easy, due to well-defined quality parameters and air-worthiness requirements.

5.1.7 Outcome uncertainty

Outcome uncertainty for quality and prices were high in both the coffee and the bunker fuel supply chain.

> "*Sample of fuel is kept by the certifying authorities present in all loadings. But how can you ascertain that the sample is actually from the fuel that is used in the ship?*"

Outcome uncertainty in the aerospace spares supply chain was high, as a part which was deemed to be of good quality can turn out to be unworthy because of either missing records or after further testing or the involvement of intermediaries. Outcome uncertainty in the recycled plastic supply chain was moderate, as quality fluctuations were not severe.

We characterise the supply chains before blockchain implementation in Table 3.

Table 3 Agency characteristics of the studied supply chains before blockchain implementation

	Characteristics of the supply chains in terms of agency factors			
Agency-based factors	*Coffee supply chain*	*Recycled plastic supply chain*	*Bunker fuel supply chain*	*Aerospace spare parts supply chain*
Information asymmetry	High	High	High	High
Goal conflict	High	High	High	Low-Medium
Length of relationship	Long	Short	Short to Long (dependent on vessel operators)	Dependent on value of transactions
Risk aversion of supplier or intermediaries	Moderate	High	Low	High
Task programmability of supplier	Moderately difficult	Moderately Difficult	Moderately difficult	Easy

Outcome measurability	Moderately difficult	Difficult	Moderately difficult	Easy
Outcome uncertainty	High	Moderate	High	High

5.2 Incentives for adoption and outcomes obtained due to Blockchain implementation

Incentivising multiple players across the supply chain is key for blockchain implementation to achieve desired outcomes (Pun et al., 2021; Jabbar & Dani, 2020).

5.2.1 Incentives for adoption and outcomes obtained – iFinca

When a farmer sells coffee that isn't fully processed (i.e. green), its cup profile is unknown. If this coffee is cupped after being sold and processed and receives a high cupping score, there are no guarantees that any bonus the exporter receives will be passed on to the producer.[5] Moreover, the amount that a producer is paid will change from one day to the next as exchange rates fluctuate. Most of the world's coffee is traded as a commodity in US dollars, which is called its C price, and this constantly changes. But producers are paid for their coffee in local currency, and all the costs they incur are paid in this currency, too. This means that if this currency becomes worthless as exchange rates change, their profitability changes.[6] Thus, farmers have high incentive to join the platform. Exporters have the incentive to join the platform if their profits are protected and their overall trade volume increases. The roasters can have visibility of the quality of the coffee and the fair price paid to the farmers, which helps them in marketing the coffee effectively. Café owners can improve brand image by providing opportunities to customers to get to know the farmer and the price paid to them, and this provides the cafés with an opportunity to engage with customers in a whole new way.

Traceability helps in verifying a coffee's country of origin, farm and producer; transparency improves awareness of the coffee's value as it moves down the supply chain, and how those involved were compensated for their work. Knowing what a producer is paid for their coffee at origin – the farmgate price – offers buyers a level of transparency that they can rely on to source coffee that is profitable, ethical and sustainably produced. The buyer has visibility of the growing process, ports, testing, roaster log etc. A QR code called Coffee Chain follows the coffee all the way from farm to café. iFinca has also developed its 'Meet the Farmer' app. Thus, the information asymmetry in the coffee supply chain has been significantly reduced due to BT implementation.

[5] https://www.ifinca.co/post/exploring-the-farm-gate-price
[6] https://perfectdailygrind.com/2020/04/how-does-exchange-rate-fluctuation-affect-coffee-producers/

Because of iFinca's BT-enabled platform, the coffee farmers are paid much better now – 20% above the cost of production. Now, with iFinca's system, farmers have more money to spend in their communities. When the producers benefit from more sustainable and profitable prices, they can create a better future for their farms, families and communities. For example, a farmer said:

> "*It will allow me to do more things. I can help other farmers. iFinca will connect all the farmers and connect them with roasters, which would not have been possible without this system.*"

Farmers also don't need to take loans anymore, where previously millers would give them loans at 35% interest.

The information also help roasters to market the coffee more effectively. Roasters will also benefit in the long term, as producers will be encouraged to keep growing the coffee that roasters sell. It also helped café owners with better customer engagement

As all players in the coffee supply chain obtain some benefits, it minimises chances of goal conflict, as people who do not join risk losing business and long-term working relationships.

5.2.2 Incentives for adoption and outcomes obtained – Plastic Bank

End-user companies have ambitious targets of using more recycled materials by 2030, but there is limited global capacity to recycle plastic. Hence, these companies want to be assured of supply of recycled plastic, and want visibility that the material supplied is indeed 100% recycled. Hence, these companies have a high incentive to join and fund blockchain implementation in the recycled plastic supply chain.

The plastic waste collector has poor quality of life. An organised system which gives them respectable living, pays them transparently and also trains them for future living, will be highly beneficial to them. Where the informal recycling system exists, some of them can run the plastic collection banks. Thus, implementation of a transparent recycled plastic supply chain can also generate employment opportunities for plastic collection banks and generate bonuses for them while recycling facilities will be assured of volumes.

Plastic Bank helped organising the waste plastic recycling trade and its blockchain-enabled system provides end-to-end transparency of the recycled plastic supply chain from collection of plastic waste, delivery to Plastic Bank collections, transportation and processing in recycling plants and final delivery to customer locations, thereby reducing information asymmetry.

“*Now everything is just entered in real time with that blockchain security. Our clients can see in real time that today this amount of plastic got picked up at this location at this time.*” Co-founder, Plastic Bank

It also made a difference to the lives of the plastic collectors. It helped in dignifying the recycling eco-system. They received more money, while Plastic Bank ensured that they have a life beyond recycling, by providing pension benefits and career training.

“*For the first time in their lives, they had ability to save and get ahead in their next stage of life. Often, women are hired to run the collection centres. A woman who has a digital account can have an advantage as she now has ability to control her finances. Thus, providing benefits across the supply chain reduced the goal conflict.”* Co-founder, Plastic Bank

5.2.3 Incentives for adoption and outcomes obtained – BunkerTrace

Vessel owners face damages to engines, resulting in breakdowns, grounding of ships and significant revenue losses. They have to cover themselves against these risks by paying high insurance fees which do not address the problem. The vessel owners also want to be absolved of allegations and potential litigation around illegal dumping of fuel. Hence, those vessel owners, as end-users, will have incentive to adopt a solution, developed by BunkerTrace. The oil refineries want to protect themselves by building reputation for delivering high quality fuel. Some unscrupulous bunker barge operators, who are part of the problem, may not be incentivised to join as partners, but if more vessel owners adopt the solution and refuse to deal with certain bunker barge operators, then those operators will stand to lose business. The insurers will stand to gain by reducing their costs, meaning they can offer discounts to vessel owners who adopt the solution.

BunkerTrace’s synthetic DNA marks the fuel, ensuring traceability from the refinery to the ship on blockchain and an application ensures that the ships can be assured of the quality of the fuel it receives. Similarly, if a ship discharges residual fuel illegally, it can be penalised or, if it has been falsely penalised, it can prove their innocence. Key refineries are also looking to create a reputation of a perfect fuel supplier with high quality and sustainability – BunkerTrace can validate the quality of the fuel they are supplying.

The technological solution of the DNA marker and the blockchain minimises information asymmetry and provides full traceability of the fuel from the refinery to the ship where it is used. This avoids the unscrupulous practice of fuel adulteration. Hence, the ships can reduce the risk of using low-quality fuel, thereby avoiding damage to the ship’s engine and the huge financial risk associated with the grounding of the ship until it is repaired. Indirectly, the risks for the insurance companies are also reduced. BunkerTrace's system does not remove any intermediaries, but it promotes fair practices in the bunker fuel supply chain. It doesn't reduce goal conflict yet, but will if a critical mass of players in the supply chain adopt it.

5.2.4 Incentives for adoption and outcomes obtained – Aviation Spares

Customers need a way to ensure the parts they are receiving are authentic, that they are getting the best prices and that they are safe from scams and potential problems. With blockchain, they are able to precisely track the parts, ensure that they are accompanied by images and quality documents and that they are immediately available for sale and shipping. This reduces information asymmetry. Thus, they can also reduce manhours verifying documentation and complete deals much faster. Thus, buyers of aviation spare parts have plenty of incentives to join the platform. Sellers who want to deal fairly and gain access to large number of customers will also want to join the platform.

The platform ensures that no spurious sellers exist in the platform, and hence the risk of transactions involving such sellers is eliminated. It also helps in reducing risks of human error in checking the cumbersome maintenance documents of aviation spare parts. Buyers of aviation spare parts have access to transparent and trusted information to make their decisions faster – reduced from months to days. Sellers also have access to a marketplace with more buyers looking at their parts, as AviationSpares offers a vast buyer base of 2,000 people from 750 potential buying companies. In fact, 25% of buyers are checking out with no price haggling, which means the seller's sales teams can spend more time selling and less time responding to quotations. Using blockchain has also significantly reduced costs, as the intermediaries who sometimes charged up to 25% are removed. Banks are also removed, which not only reduces the associated costs but also speeds up the procedure and makes instant payments and commissions available. Thus, AviationSpares is the only case that played a role in removing some intermediaries. The details provided by its blockchain-enabled platform and the ease of conducting transactions removed some intermediaries involved in the used aviation spares trade.

5.3 Outcome-based mechanisms

The primary outcome-based mechanisms identified from the cases are tracking and tracing the products across the supply chain with user-friendly mobile applications, developing customised and secure payment systems, technical support for suppliers and farmers and adaptation to local conditions. These mechanisms facilitate the adoption of blockchain and play key roles in generating the outcomes.

5.3.1 Developing user-friendly applications

Tracking and tracing the products across the supply chain with a record of all transactions and other data points provides transparency and visibility to customers and minimises risks of poor quality and adulteration. Such visibility, for example of the farmgate price and other data, enables iFinca's customers not only to be sure of the quality but also to ensure that farmers are paid adequately. iFinca's QR code called Coffee Chain allows people involved with that coffee in the supply chain have access to all the data such as farmgate price, growing process, ports, testing, roaster log etc. This information is provided on a permission-only basis; this means that different supply chain members will only see the information they're allowed to view, and competitors can't view it at all. The Coffee Chain QR code is specific to every individual order. Such a security system encourages that only registered buyers will have access to the information and not anybody else – for example, competitors. The visibility brings direct benefits to the farmers. Farmers are getting paid a lot better now – 20% above the cost of production. In 1983 price was 1.23 USD.

> "*Prices have been increasing for a cup of coffee but farmers are being paid less. For a 4 USD cup of coffee, a farmer only got 3–4 pence. Now with the iFinca system, farmers have more money which they can spend in the community. When the producers benefit from more sustainable and profitable prices, they can create a better future for their farm, family, and community*."

Similarly, the fuel tag and flasher developed by BunkerTrace stay in forever if the oil has been marked. If it comes from a refiner which has installed their tag, BunkerTrace can track it. The BunkerTrace system can safely detect 2 million tags at a time, and can thus check the history of the parts of the fuel.

> "*The insurers who insure vessel owners pay for pollution and violation are beginning to offer a discount in premium if they use BunkerTrace product. Their biggest expenditure is on illegal pollution and fines. Vessel owners do not want any violations. They have a crew on board who will be held up and that is dead money. They face risks of physical damage due to repair of engines and the direct cost of millions and indirect costs of laying up, demurrage, reputational risks. By implementing BunkerTrace systems, such risks are minimised.*"

5.3.2 Developing customised and secure payment systems

Digital payment systems or instant payments are key to the success of the blockchain-based platform, so that the sellers can receive immediate and secure payments. For example, Plastic Bank pays market rate plus a bonus payment and a deposit into a pension and insurance scheme for the collector. The Plastic Bank branch owner also gets a bonus. When collectors make more money, more volumes come in and branches make more money. It becomes a good business to be a Plastic Bank certified partner, and costly to flout rules and use child labour, etc.

Plastic Bank partners with local cooperative banks in some communities and choose the most accessible system for payments for a particular community. For example, they partner with a local payments service provider in Indonesia, which has 20 million users for their digital wallet and thus collectors can cash out their Plastic Bank tokens using their service provider account. Plastic Bank can still operate without digital payment partner and collectors can get paid digitally with redeemable e-coupons or by cash. Tokenised digital savings and wallets on blockchain platforms also ensure the security of the system. The benefits of such digital payment systems for collectors is significant. For example, one recycled plastic collector in Haiti is illiterate and widowed, with a large family to support:

> "*Now she makes enough for the family, all her kids go to school, she has learnt to read, had her first digital bank account, has a phone for the first time. She has onboarded other people. We empower them to use recycling as a way to get to the next stage of life. They have first time ability to have savings. We often target women to run our collection centres. A woman who has a digital bank account can have a huge advantage as if a woman brings cash, the husband decides what to do with it. She now has can control her finances*."

iFinca also fixes the exchange rate at the time of placing an order. Thus, currency fluctuations are less of an issue:

> "*Once an order is accepted by the farmer and exporter, an exchange rate is fixed, and the farmer will see it in their local currency. If the producer has a 100 kg order and they don't agree with the price, they just cancel it. When the farmgate price is agreed upon and if it is more than what farmer was paid before, the farmer gets the notification that he owe more based on the quantity he delivered.*"

5.3.3 Providing technical support for supplier or farmer

Support for suppliers and farmers is also needed to encourage them to join the platform and reap the benefits. iFinca keeps producers informed by providing them with an integrated calculator to determine their coffee's parchment price. The calculator uses the yield factor – a formula which calculates how many kilos of parchment are needed to produce a 70 kg sack of exportable green coffee. This piece of information provides an opportunity for farmers to negotiate better prices. AviationSpares also provides automated quality assurance of the documents provided by suppliers for the parts they want to sell. As documentation requirements for aviation spare parts trade are very high, a lack of requisite details may not result in a trade.

5.3.4 Adapting to local conditions

Adapting to local conditions is also key. iFinca wanted to have encrypted QR code for each sack of coffee beans. One farmer had a better idea: "*Unless it is in the hands of real people, you don't know whether it will work.*"

Plastic Bank also had to adapt to local conditions. For example, in Haiti, they had to first use solar power to charge phones and access wifi before they could implement their system.

> "*How will it look when we go to a community where processors are not used to using any system, collectors do not use phones? We need a way how to work in reality. Fintech solution can be the third thing in your plan. We first used solar power for phone charging and for charging the wifi, which now allows the phone to work in the community. We also conducted literacy programmes and phone usage training.*"

5.4 Behaviour-based mechanisms deployed by the technology service providers

The behaviour-based mechanisms, identified from the case studies, which the BT service provider can deploy, are involving locals, building local relationships and educating and engaging customers.

5.4.1 Involving locals and building local relationships

Building a relationship with the coffee farmers was key to the success of the adoption of the blockchain-enabled platform. iFinca's CEOsaid:

> "*Right now we do not face any no push back. We have built good relationships. The whole team is Colombian, so there is trust and now there is a good track record. With word of mouth, there is a queue to join the platform.*"

Plastic Bank also built a relationship with players from the existing plastic recycling eco-system, and involves them or builds new eco-systems by involving locals:

> "*Where the existing eco-system exists, we offer the ability to include them instead of competing with them, certify them to be Plastic Bank locations. They have to follow our codes of conduct, use our digital system, register members, and continuously pass our audits and checks and become eligible for a bonus system. Where there is no existing recycling eco-system, we cooperate as train the trainer and get the community to select someone to run the Plastic Bank location.*"

5.4.2 Educating customers

We learnt from the interviewee from BunkerTrace how avoiding misconceptions and educating customers about the technology was necessary. He mentioned that:

> "*People may have a perception that putting an additive into oil may also damage the engine. But the first thing we have to understand is that the amount we are putting in is minute, i.e. 1–2 parts per trillion. The amount of product we use is less than 2 ft compared to the flight distance between London and New York. Hence, we had to engage in an educational programme with people to educate that our product will not damage the engine.*"

We learnt from a coffee farm owner in Honduras about iFinca's effort in educating roasters. Al said:

> "*iFinca has done a much better job in educating the roasters. It will allow me to do more things. I can help other farmers. iFinca will connect all the farmers and connect them with roasters.*"

5.4.3 Engaging with customers

iFinca developed its 'Meet the Farmer' app by which customers at the café can scan QR code and point a phone camera. Thus, the customers can receive information about the brand, purchase date, the global market price on that day, the price paid to the farmer, farmer, farm name, farmer photos, size of the farm, certificates. They can also see the picture of the farmer and message him or her. In the words of a coffee shop owner, "*iFinca gives extra support for customer engagement- another thing to talk to customers. Coffee is a doorway to many things. Customer can engage in a whole new way. Wonderful reaction from customers*. *We participate in a farmer's market in New York and people were intrigued to know about the farmgate price".*

AviationSpares also recognises the importance of the user-friendliness of the platform, and paid particular attention to its consumer portal to engage better with sellers and buyers:

> "*Millennials are joining the workforce. They will like to have the same experience while buying and selling aviation parts as they would like to have for personal buying*."

Table 4 Summary of observed behaviour and outcome-based mechanisms

		Outcome-based mechanisms				**Behaviour-based mechanisms**		
Case	*Focus of the case*	*Developing user-friendly applications/ user interface*	*Developing customised and secure digital payment systems*	*Providing technical support for suppliers or farmers*	*Adapting to local conditions or customer needs*	*Involving locals and building relationships*	*Educating the customers*	*Engaging with customers*
iFinca	*Social sustainability*	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Plastic Bank	*Social sustainability*	Yes	Yes		Yes	Yes		
Bunker Trace	*Risk reduction (quality and financial risk)*	Yes			Yes		Yes	
AviationSpares	*Risk reduction (quality risks and risks of human error)*	Yes		Yes	Yes			Yes

5.5 Impact of mechanisms on social sustainability and risks and proposition development

We analysed the roles of the different outcome and behavioural mechanisms in improving social sustainability and in reducing risks. Our analysis of the iFinca and Plastic Bank cases shows that customised, secure and transparent payment systems are needed so that the supplier or farmer experience the benefits of a blockchain-enabled track and trace system. Both cases also demonstrated the importance of adapting to local conditions and building local relationships.

The legacy supply chains for both the cases also demonstrated high levels of information asymmetry, goal conflicts and similar task programmability of suppliers. These supply chains demonstrated different levels of outcome measurability, outcome uncertainty, risk aversion of suppliers or intermediaries and lengths of relationships. In such contexts, while working with a disadvantaged community who are potentially exploited, outcome-based mechanisms ensuring fair payment and adapting to local conditions, supported by the behavioural mechanism of building local relationships, are needed to ensure that the social sustainability benefits reach the community.

Additionally, iFinca provided an integrated price calculator for the coffee farmers to also provide visibility to its farmers, as the information asymmetry was high and farmers previously received no information about the downstream supply chain. It also engaged in customer engagement so that both the end-customer and the farmer could learn about each other, while Plastic Bank empowered the plastic collectors to use recycling as a way to invest in health insurance, sanitary products and career training. Both iFinca and Plastic Bank focused on developing scalable solutions.

BT has the potential to contribute to social supply chain sustainability by making information immutable. As the information cannot be modified without consent by authorised actors, BT can prevent corrupt individuals or organisations from unfairly seizing personal assets, and can hold the corrupt accountable for their misdeeds. It can help in the assurance of human rights and fair, safe work practices. It can also instil confidence in customers that goods being purchased are from ethical sources (Saberi et al., 2019). With blockchain-led transparency, economic injustices such as slavery and exploitation of workers in the global commodity markets can be alleviated (Kshetri, 2021). Moreover, behavioural mechanisms and social practices can be effective in improving sustainability performance (Shafiq et al., 2017). Outcome-based approaches are also needed to implement BT in the supply chain. Moreover, the choice of outcome and behavioural mechanisms and the complementarity between them may also vary depending on the profiling of the legacy supply chain in terms of specific agency factors. This leads to our first set of propositions:

P1a: The relationship between the adoption of a blockchain-enabled system and social sustainability outcomes is expected to be mediated by the use of outcome-based mechanisms of development of user-friendly applications and interfaces, customised and secure digital payment systems and adaptation to local conditions along with the behaviour-based mechanisms of building local relationships via the BT service provider.

P1b: The relationship between the adoption of blockchain, outcome and behaviour-based mechanisms and social sustainability in the supply chains will be influenced by agency characteristics of the legacy supply chain in terms of information asymmetry, goal conflict and task programmability of suppliers.

We illustrate Proposition 1 in Figure 1.

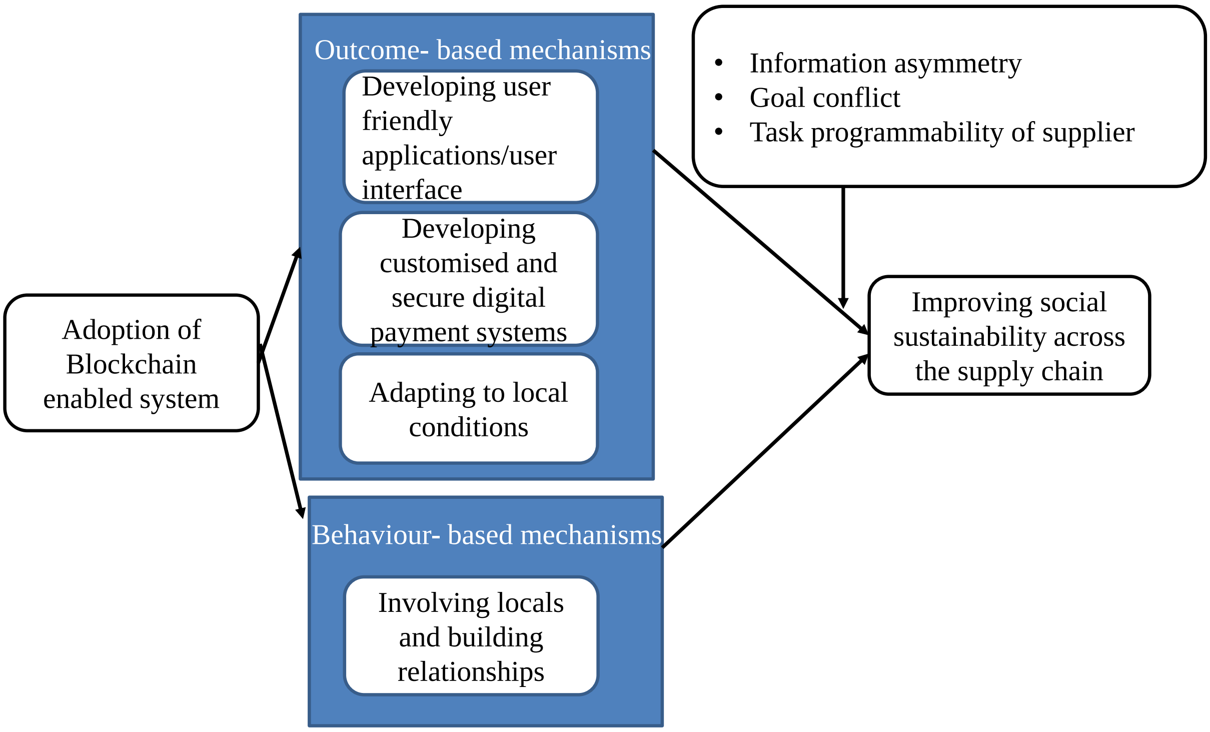

Figure 1 The role of outcome and behaviour-based mechanisms in improving social sustainability in supply chains

BunkerTrace and AviationSpares cases demonstrate that implementing blockchain-enabled tracking and tracing systems can directly help in minimising supply chain risks. BunkerTrace solutions help in avoiding fuel quality risks for shipping companies, which in turn avoids risks of idling due to damaged engines, and the huge financial and insurance risks associated.

AviationSpares also helps in reducing quality risks associated with spurious spares and risk of human error in checking documentation. Outcome-based mechanisms of development of user-friendly applications or user interface and behavioural mechanisms of customer education and/or customer engagement to encourage and enrol customers to use the blockchain platform help improve the impact of implementing the blockchain platform in reducing the above risks. The bunker fuel and aviation spare parts supply chain also exhibit high levels of information and outcome uncertainty while demonstrating different characteristics in terms of other agency factors. As outcome measurability is moderately difficult in the bunker fuel supply chain (while it is relatively easy in the aviation spare parts supply chain) customer education and a process of challenging misconceptions about the benefits of track and trace technologies assume more prominence in the bunker fuel supply chain, while customer engagement through improved user interfaces is more relevant for the aviation spare parts supply chain.

BT provides transparency and can potentially remove intermediaries from transactions, hence mitigating the opportunistic behaviour. As information is shared among supply chain participants and distortion of information is much less likely while using BT, opportunistic behaviour like violation of agreements and concealing critical information is more difficult when compared with traditional supply chains (Saberi et al., 2019). Thus, BT can reduce opportunism risks in the supply chain which manifests itself in terms of suspect quality.

Behaviour-based approaches play key roles in risk management (Zsidisin & Ellram, 2003) and are needed for BT implementation. Similarly, as our cases demonstrate, outcome-based approaches are also needed to implement BT in the supply chain. Moreover, the choice of outcome and behavioural mechanisms and the complementarity between them may also vary depending on the profiling of the legacy supply chain in terms of specific agency factors. This leads to our second set of propositions:

P2a: Adoption of a blockchain-enabled system will have a direct effect on reducing quality, financial and human errors related risks in the supply chain. It will also require the use of outcome-based mechanisms such as the development of user-friendly applications or user interfaces and behaviour-based mechanisms of customer education or customer engagement.

P2b: The relationship between the adoption of blockchain, outcome and behaviour-based mechanisms and risk reduction in supply chains will be influenced by agency characteristics of the legacy supply chain in terms of information asymmetry and outcome uncertainty.

The relationships outlined in Proposition 2 are shown in Figure 2.

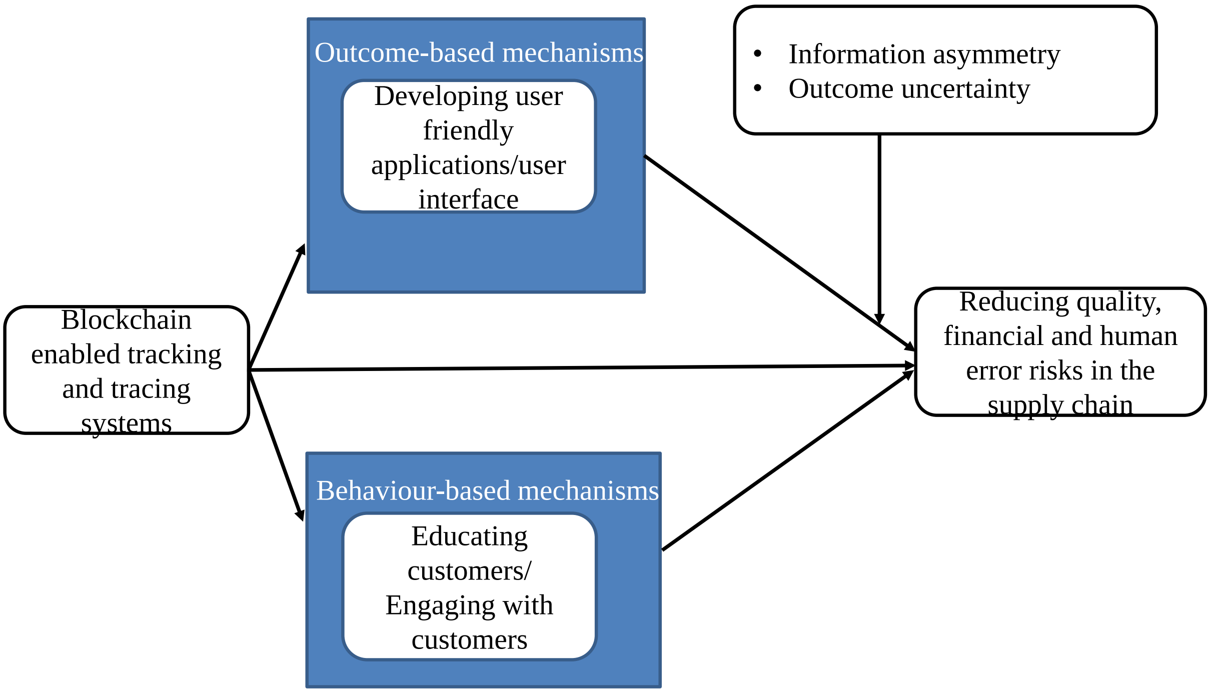

Figure 2 The role of outcome and behaviour-based mechanisms in reducing risks across the supply chain

6. Conclusion and future research opportunities

6.1 Summary of findings

Improving social sustainability and minimising risk across the supply chain using blockchain will require particular attention to outcome-based and behavioural mechanisms, as BT service providers emerge as unique agents in the supply chain. The cases demonstrate that the role of these mechanisms will vary depending on the outcomes and nature of the agency relationships in legacy supply chains. In this research, we identify outcome-based and behavioural mechanisms which BT service providers can deploy to improve social sustainability and to reduce risks across the supply chains. Our analysis results in propositions that the implementation of blockchain-enabled track and trace systems can directly reduce risks in supply chains, along with the deployment of outcome-based and behaviour-based mechanisms as potential mediators. But the improvement of social sustainability in supply chains can only be obtained by deploying suitable mechanisms.

6.2 Theoretical contribution

There is a lack of understanding of the specific outcome and behaviour-based mechanisms needed for blockchain implementation to improve sustainability and risk management in supply chains. This research addresses this gap and identifies mechanisms, such as developing user-friendly applications or interfaces, developing customised and secure digital payment systems, providing technical support for suppliers, adapting to local conditions, involving locals and building relationships, educating and engaging with customers. Hastig and Sodhi (2020) identified technical capabilities, organisational readiness and other capabilities needed for change for organisations implementing blockchain solutions. But, Hastig and Sodhi (2020) do not elaborate on the mechanisms by which blockchain service providers can generate the desired outcomes from blockchain implementation.

The results demonstrate how relationships between the mechanisms and outcomes vary for social sustainability and risk reduction. Past research on blockchain adoption in supply chains are mainly atheoretical in nature and do not provide a theoretical framework that is grounded in real applications (Tan et al., 2020). Thus, we respond to the call by Treiblmaier (2018) to conduct theory-driven research on blockchain adoption in supply chains and contribute by identifying specific outcome and behaviour-based mechanisms needed to improve social sustainability and reduce risk in supply chains.

6.3 Managerial implications

Our research provides insights for BT service providers to pay particular attention to specific outcome-based and behavioural mechanisms needed to improve social sustainability and reduce risks in supply chains. Such insights are expected to improve the success of blockchain implementation beyond pilot projects. Similarly, it will also guide user organisations on how to engage with BT service providers to achieve specific supply chain outcomes. It is important that service providers acknowledge that BT is not a plug-and-play solution, and improving the technology alone may not address the problems faced in practice unless the suitable outcome and behaviour-based mechanisms are put in place. Our research contributes to that, and will make BT service providers aware of what is needed to achieve the desired outcomes from blockchain implementation. The role of the mechanisms will vary depending on the desired outcomes and the agency characteristics of the legacy supply chain such as information asymmetry, goal conflict and task programmability of suppliers for social sustainability and on information asymmetry and outcome uncertainty for risk reduction. Our research goes beyond the hype and conceptual papers to analyse real BT implementation projects to derive insights. Our results can provide guidance to future implementation, particularly focusing on improving sustainability and for reducing risks in supply chains. Our conclusions will also be valid for other blockchain implication cases, such as cobalt or diamond mining, which provides traceability solutions for customers and social sustainability benefits to those involved in the mining.

6.4 Limitations and scope for future research

Our study has certain limitations. It is based on four in-depth case studies. Future research can try to focus on some exemplar case studies of successful BT implementations, and potentially some failures. There is also a need to understand the role of different agency factors in legacy supply chains as drivers for BT implementation. The relationships of the mechanisms to the outcomes can also vary depending on the agency relationships observed in the legacy supply chains prior to BT implementation, which requires further investigation using a larger number of cases, profiled based on agency factors. Further empirical research is needed to validate our propositions. The relationships between the mechanisms and between the mechanisms and the performance outcomes of BT projects can also be explored in future research. Finally, the objective of this research is to understand what is needed to improve implementation of blockchain solutions to achieve social sustainability and to reduce risks in the supply chain – not to improve the technological aspects of the blockchain solutions. Hence, our focus is on execution and implementation and not on technological development of the blockchain solution. Researchers can also focus on understanding user needs to improve the technical aspects the blockchain solutions.

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Appendix: 1st and 2nd order codes

1st order code from the case documents	2nd order code	Types of mechanisms
A QR code which follows the coffee from farm to café	Developing user-friendly applications	**Outcome-based mechanisms**
An application which can be used on the vessel to identify the supplied fuel to the ship with that supplied by the refiner and marked with a unique code		
Easier to post all information when dismantling an aircraft, thus providing access to repair history		
Application works for every user type- collectors, branch operator, processor, client		
Developed tokenised digital savings and wallet and money is deposited in the member's account so that they can store in digital savings or redeem right away	Developing customised and secure digital payment systems	
Payment to the farmer as per the agreed farmgate price and exchange rate fixed at the time of acceptance of the order		
Automated quality checking process of the paper work to avoid errors	Providing technical support	
Providing farmers with an integrated calculator to determine their coffee's parchment prices		
Partner with local cooperative banks, which are most accessible to the local community	Adapting to local conditions	
Use the farmer's idea for encrypting QR code on the sack		
Had to focus on solar-powered phone charging and wifi before implementing blockchain solution		
Local team built good relationships and generated trust	Involving locals and building local relationships	**Behaviour-based mechanisms**
Cooperated as train the trainer, got the community to select someone to run the Plastic Bank		
Engaging with the millennial users who want same online experience while transaction in their work as their online buying in personal life	Engaging with customers	

Enabling the customer to leave message for the farmer by using the app		
Customer should be able to engage with the app in a whole new way		
Communicating how the system works with all partners	Educating customers	
Changing the perception of customers through educational programme		

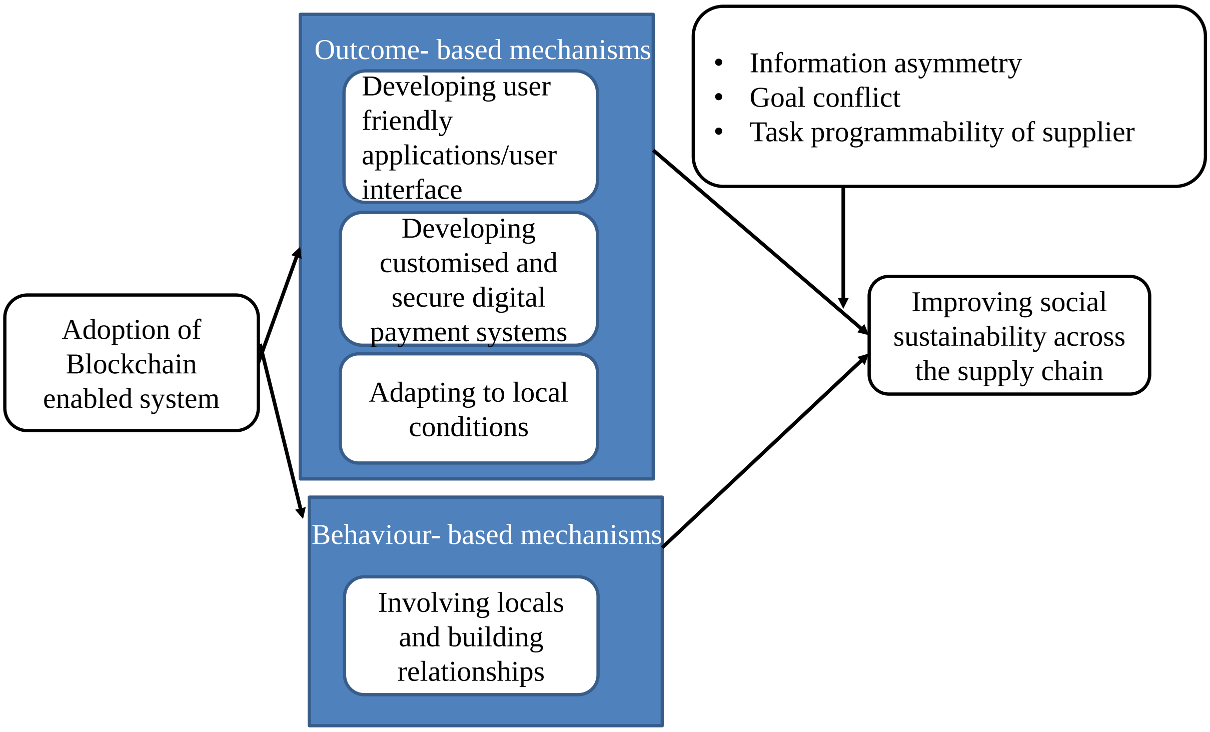

Figure 1 The role of outcome and behaviour-based mechanisms in improving social sustainability in supply chains

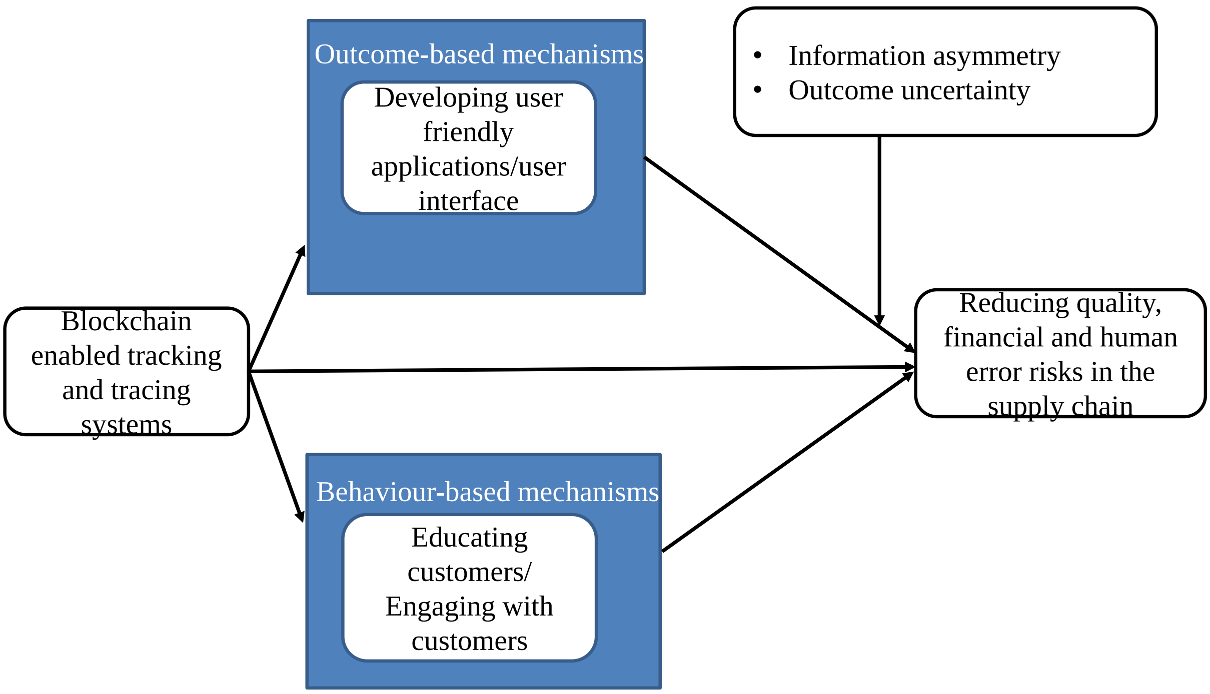

Figure 2 The role of outcome and behaviour-based mechanisms in reducing risks across the supply chain

Table 1 Details of the interviews conducted

Case company	**Designation of the interviewee(s)**	**Duration of the interview**	**Industry sector**	**Outcome**
iFinca	CEO interview 1 CEO interview 2 CEO interview 3 Coffee farm owner Café owner	68 minutes 30 minutes 21 minutes 30 minutes 32 minutes	Coffee	Social sustainability
Plastic Bank	Co-founder 1 Co-founder 2	47 minutes 22 minutes	Recycled plastic	Social sustainability
BunkerTrace	Co-founder (interview 1) Co-founder (interview 2) Co-founder and technical architect	60 minutes 42 minutes 23 minutes	Bunker fuel for shipping	Risk management
AviationSpares (anonymised)	Senior R&D Manager 1 Senior R&D Manager 2	56 minutes 20 minutes	Aviation spare parts	Risk management and efficiency improvement

Table 2 Ensuring validity and reliability of the research

Quality of research design	**Case selection**	**Data collection**	**Data analysis**
Construct validity		Triangulated data: interviews, news articles, LinkedIn posts, company documents (Yin, 2017) Use of highly knowledgeable informants (Eisenhardt, 1989)	Establish and maintain a chain of evidence Use of case study protocol (Ellram, 1996; Yin, 2017) Draft reports viewed by key informants (Ellram, 1996)
Internal validity	Cases were chosen for different type of blockchain implementations across industries; cross-case analysis was conducted	Use of knowledgeable respondents, directly involved in the blockchain implementation projects	Pattern-matching among cases (Yin, 2017)
External validity	Multiple-case study approach (Ellram, 1996, Yin, 2017)	Gathering data on the case context	Consideration of case context (Eisenhardt, 1989)
Reliability	Established a chain of evidence including case study protocol and list of potential cases (Ellram, 1996; Yin, 2017)	Semi-structured interview guide included in case study protocol (Yin, 2017)	All interview transcripts analysed by interviewers (Yin, 2017)

Table 3 Agency characteristics of the studied supply chains before blockchain implementation

	Characteristics of the supply chains in terms of agency factors			
Agency-based factors	*Coffee supply chain*	*Recycled plastic supply chain*	*Bunker fuel supply chain*	*Aerospace spare parts supply chain*
Information asymmetry	High	High	High	High
Goal conflict	High	High	High	Low-Medium
Length of relationship	Long	Short	Short to Long (dependent on vessel operators)	Dependent on value of transactions
Risk aversion of supplier or intermediaries	Moderate	High	Low	High
Task programmability of supplier	Moderately difficult	Moderately Difficult	Moderately difficult	Easy
Outcome measurability	Moderately difficult	Difficult	Moderately difficult	Easy
Outcome uncertainty	High	Moderate	High	High

Table 4 Summary of observed behaviour and outcome-based mechanisms

		Outcome-based mechanisms				**Behaviour-based mechanisms**		
Case	*Focus of the case*	*Developing user-friendly applications/ user interface*	*Developing customised and secure digital payment systems*	*Providing technical support for suppliers or farmers*	*Adapting to local conditions or customer needs*	*Involving locals and building relationships*	*Educating the customers*	*Engaging with customers*
iFinca	*Social sustainability*	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Plastic Bank	*Social sustainability*	Yes	Yes		Yes	Yes		
Bunker Trace	*Risk reduction (quality and financial risk)*	Yes			Yes		Yes	
AviationSpares	*Risk reduction (quality risks and risks of human error)*	Yes		Yes	Yes			Yes