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Abstract:

The implementation of blockchain technology holds promise for improving social sustainability and minimizing risks across the supply chain. A theory-driven analysis of how blockchain implementation affects social sustainability and minimizes risks (outcomes), is missing in the 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 to reduce risks through blockchain projects using agency theory as the 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 minimize 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, frauds, 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 minimizing risks is the cobalt (Co) supply chain for electric vehicles. It is estimated that about 25% of cobalt that is mined from Congo uses child labour and due to its high quality, is adulterated with low quality cobalt from other countries. As a result of this adulteration, a car manufacturer is unable to explicitly state that the cobalt used in its products has been responsibly sourced (Cassidy, 2020). Traceability using blockchain can ensure that fair practices are followed and help an automotive manufacturer minimize 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 the farm (Hintze, 2019). Despite the potential of BT, it has only started receiving attention recently in the 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 the quality of life and drives decision-makers to consider their decisions' potential social consequences (Mani et al. 2016). Hence, it can be considered as 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 and Kauppi, 2014; Nakamba et al., 2017). The social sustainability dimension has been emphasised mainly to satisfy legal requirements, human safety or legislative framework (Gualandris and Kalchschmidt 2016; Sodhi and Tang 2018), leaving the area of innovations for social sustainability largely unexplored (Orji et al., 2020).

The 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 for supply chain risk management (Ivanov et al., 2019). Katsaliaki et al. (2021) mentions that there is a need of case studies and surveys to test whether implementing BT decreases risks in terms of opportunistic behavior of 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. What is particularly missing in the SCM literature is the theory-driven analysis of real blockchain implementation case studies across industries focussing on social sustainability and risk minimization as the outcomes. 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 above mechanisms vary as per the context of the different projects?

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

2. Literature review

2.1 An overview of Blockchain Technology (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 to address several operational challenges in manufacturing and service industries (Jabbar and Dani, 2020). BT, which started initially as a technology for financial services, has now expanded in sectors such as food, transport, logistics, etc. (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, decentralization, consensus, and distributed trust (Treiblmaier, 2019). Immuability 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. Decentralization implies no central authority is needed to validate the 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 third party for the management of financial transactions (Wang et al., 2019). BT aids in resolving the issues related to trust and also 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 capability to generate all the records (Kamble et al., 2019; Ren et al., 2020). However, the effective implementation of BT also has several challenges such as lack of organized eco-systems, governance of data, concerns on privacy, high implementation costs, etc. (Kamble et al., 2019). The benefits and effectiveness of BT in most of the industry 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 and Wamba, 2019). BT can help in significant transformation of logistics and supply chain operations (Saberi et al., 2019; Choi, 2020). A major challenge in a supply chain is tracing of products and data management systems (Azzi et al., 2019). BT can help address the challenges associated with tracking of products as well as management of data. Tracking and tracing facilitate the prediction of hazardous events and prepare for managing such events.

The application of BT can help identify the activities of supply chain entities on a real-time basis (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 optimizing 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 also 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 frauds related to products in a supply chain (Chen, 2018). As a consequence, supply chains will improve in terms of economic and operational performance (Queiroz and Wamba, 2019). Implementation of BT also results in increased cooperation among the supply chain entities (Aste et al., 2017), efficient management of supply-demand, and reduction in inventory costs (Ivanov et al., 2019). For example, in an agricultural supply chain, the implementation of BT eliminates intermediate entities, ensures traceability, and transparency, which increases efficiency and reduces risks (Yiannas, 2018). In the food supply chains, provenance and information traceability improves the quality and safety of food. BT can contribute significantly to the food supply chain by bringing improvements in transparency, accountability, and traceability (Kamble et al., 2020). BT has also been implemented in the food industry for ensuring payments in a fair and fast manner to small farmers (Wang et al., 2019). BT also has potential benefits for improving information, financial, and logistics 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 subsequent consequences. Therefore, firms can plan mitigation steps and reduce the risks of any disruption. For example, in shipping industry, the visibility provided by BT can aid customs authorities to have availability of more information for analyzing the risks (Wang et al., 2019). This can eventually result in increased security and safety, and greater efficiency in border clearance procedures.

BT can also in avoiding fraudulent transactions and security risks (Katsaliaki et al. , 2021). There are several industries, such as luxury, wine, medicines, etc., in which there are risks associated with the counterfeiting of products (Kshetri, 2018). According to Wall (2016), there are 120,000 deaths in Africa due to fake malaria drugs. Similarly, the adulterated food sold around the world is estimated to be around 10%. Thus, risks related to counterfeiting of products must be reduced. BT can help mitigate such risks through the facilitation of tracking and tracing of raw materials and finished goods (Mackey and Nayyar, 2017; Wang et al., 2019), and makes it easy to detect any counterfeiting through verification of the authenticity of data. Some of the manufacturing firms have also started to integrate BT in production processes (Xu et al., 2018), to eliminate the risks associated with counterfeit of products in a supply chain. Due to transparency in the processes, BT can also encourage ethical behaviour and reduce risks related to unfair practices such as exploitation of suppliers or 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 adoption of BT for improving sustainability in the supply chain (Bai and 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 the 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" (Lafferty and Langhelle, 1999). In a supply chain, social sustainability refers to the issues related to processes and products, which impact stakeholders (Klassen and Vereecke, 2012; Mani et al., 2016). Socially sustainable practices involve re-designing the supply chains (Pagell and Wu, 2009) and helping organizations attain sustained competitive advantage (Klassen and Vereecke, 2012).

BT helps in integrating social sustainability in the supply chain by making information immutable and ensuring transparency (Hastig and Sodhi, 2020; Saberi et al., 2019; Bai and Sarkis, 2020). Collaboration and knowledge sharing in the Blockchain can help in achieving social responsibility goals (Upadhyay et al., 2021). Indeed, application of BT can aid in addressing several social sustainability concerns (Hastig and Sodhi, 2020; Saberi et al., 2019) such as tracking social conditions, which can cause concerns on safety and health (Adams et al., 2018), detecting unethical suppliers and counterfeit products, as the information is recorded by authorized entities (Saberi et al., 2019), and preventing unfair seizing of assets by corrupt organizations and individuals since information can't be altered without the consent of authorized entities (O'Dair, 2016). Many customers are now increasingly demanding information from firms on the source of raw materials. In this regard, ethical and responsible sourcing has gained increased consideration in several organizations. 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 and Yee, 2012). This will help customers to have complete assurance about the origin of raw materials and reduce any 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 the fair-trade use "antiquated" techniques, but much superior and better results can be achieved with blockchain (Kshetri, 2018). Few organizations have used BT to ensure their customers about raw materials and reduce any associated risks. For example, Martine Jarlgaard (Fashion designer based in London) offered the customers with garments enabled by BT. Customers can track the authentication process of raw material (fleece) and downstream processing steps. This process makes the customers assure on the origin of raw materials and reduces any perceived financial risks (Montecchi et al., 2019). Peer Ledger is using BT for ensuring responsible sourcing of gold (Peer Ledger, 2020). IBM has collaborated with RCS Global and Ford for the development of the Blockchain platform to ensure responsible sourcing of cobalt.

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

2.5 Theoretical support for analyzing 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 is that:

- potential goal conflicts exist between principals and agents;
- each party acts in its self-interest;
- information asymmetry frequently exists between principals and agents;
- agents are more risk-averse than the principal; (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 the principals' and it is difficult or expensive to verify whether agents have appropriately performed the delegated work. This problem also arises when it is difficult or expensive to verify that agents have the expertise to perform the delegated work that 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 the above problems, agency theory prescribes two types of mechanisms- outcome-based and behaviour based- to address these problems (Rungtusanatham et al., 2007). Outcome-based mechanisms emphasize results (Choi and Liker, 1995), while behaviour-based mechanisms emphasize tasks and activities in the agent’s processes. Agency costs within Principal-Agent Theory can be defined as the principal's monitoring expenses, bonding expenditures by the agent, and residual loss (Jensen and 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 emphasizes results regardless of how the agents achieve them (Choi and Liker, 1995). The other management mechanism is behaviour-based. When this mechanism is taken, principals can use behaviour controls to monitor agents’ behaviours and efforts which otherwise are unknown to the principals. The behaviour-based management mechanism emphasizes tasks and activities in agents’ processes that lead to the agents' outcomes (Eisenhardt, 1989; Ekanayake, 2004).

In the context of BT implementation across the supply chains, the blockchain service providers are playing the roles of intermediates or agents to alleviate the agency and 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 the blockchain technology service providers to improve social sustainability and to minimize risks across the supply chain.

2.7 Gaps from 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 in an earlier phase, and most of the 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 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 and Sodhi, 2020). Behnke and Janssen (2020) identified the boundary conditions needed for traceability in food supply chains using blockchain. Tönnissen and Teuteberg (2020) provides insights into how blockchain and (dis-) intermediation will change existing concepts in the operations and SCM. But, there is a lack of theory-driven analysis on how BT can improve social sustainability and minimize risks across the supply chain, and the role of blockchain service providers. Theory-driven research allows for 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 blockchain technology service providers can deploy to improve social sustainability and to minimize 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 risks across the supply chain (Yin, 2018). Finally, we seek to develop propositions that link new outcome-based and behavioural mechanisms deployed by BT service providers to improve social sustainability and to reduce risks.

In this regard, we collected news articles on Blockchain applications in SCM using Factiva using 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 the BT projects between January 2017 and December 2019. 43 news articles were obtained about specific blockchain implementation projects out of which 23 cases were shortlisted based on whether they improve social sustainability or minimize risks 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 the interview. Finally, we got confirmation from people involved in 4 different blockchain implementation projects - two focused on improving social sustainability, and two focused on reducing risks across the supply chain. People from 4 companies agreed to be interviewed by us for this research. Other 19 companies did not respond to our request.

Semi-structured in-depth interviews were conducted with the 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 the company websites and requested from the companies. Secondary news articles were also used. The additional material collected for iFinca included LinkedIn posts by the company, and transcripts of two podcasts named "Guranteed Fresh" made by iFinca CEO. All these documents along with the interview transcripts formed the case document for iFinca, which was coded. For PlasticBank, the additional material included LinkedIn posts and a document shared by Plastic Bank CTO titled "*Plastic Bank's Successful Journey with Blockchain*." Additional material collected for BunkerTrace included an interview of the CEO which got 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 by the key informants over 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 collected additional material). 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, 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 are also validated with 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	1. CEO- interview 1 2. CEO interview 2 3. CEO interview 3 4. Coffee farm owner 5. Owner of cafe	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 (anonymized)	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, and company documents (Yin, 2018) 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 and 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 (Ellram1996, Yin2017)	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 for the end customer to know the farmer and another for the players to have visibility of all the transactions. CEO of iFinca met a coffee farmer and realised that the farmers were not able to negotiate prices, were disconnected from therest of the the supply chain and were price takers.

Characteristics of the blockchain and rationale for using it:

First part of iFinca's blockchain platform is private and permissioned from the farm till the café. Only a buyer or seller of the coffee is on the platform and have access to the information. At the café, some of the 160 data points becomes public like the farmgate price and who the farmer is as any customer will 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 source ethically sourced coffee and wants to ensure that the farmer has been paid a fair price, he 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 farm-gate 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

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

with a high FOB price may assume that the producer takes home all or most of this amount. In reality, they don't. 40-80% of FOB and even lower was being 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 blokchain helps us in doing that"*.- CEO of iFinca

We are a unique 3rd 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-kilogram sack of exportable green coffee. Thus, iFinca makes the farm-gate-price available to all buyers and collects 160 data points 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. added inventory systems, and carriers can also be added. It uses a QR code called Coffee Chain which follows the coffee from farm to cafe. 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 "Meet the Farmer" app by which customers at the café can scan another QR code, point a camera of their phone. [2]A page comes up and gives the customers the 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. 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 to the farmers.

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

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 collected material is processed to produce what is known as Social Plastic® which is 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 experienced a huge amount of plastic on the beach and in water. This experience coupled with the realization that value can be generated by recycling plastic motivated him to start Plastic Bank. Many of the global manufacturers have pledged to use recycled plastic but the current world capacity of recycled plastic is only 10% of that demand. Moreover, there is a high risk of having unfair practices in such a disorganized 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, by colour. The plastic collection branch uses the Plastic Bank developed application to load up collector's account type and the value is deposited in the collector member's account so that they can store 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 and the recycled plastic is converted to bales or flakes or palletized. It is then transported to the customers' facilities to be used for producing finished products.

Characteristics of the blockchain and rationale for using it: Plastic Bank uses a private blockchain with a customized token system in which it writes all the consensus rules in the system. It also uses a tokenizer reward system to reward the 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 pain 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*

[3] https://plasticbank.com/about/

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 digitize our reward programs 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 are procuring recycled plastic sing 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. Bunker Trace 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 a test onboard before loading. This allows operators and managers to make an informed decision 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 engines being damaged because of poor quality of fuel.Vessel owners thought they were buying the certain quality of fuel and the vessel will go to a loading point, have a certificate in a piece of paper and load the fuel. But, the vessel would break down in weeks time or there was severe damage to the engine. An investigation would reveal fuel was not of the quality ordered. Hundreds of such incidents happen in a year. Now, there is a new regulation that sulphur content

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

should be less than 0.5% and 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 owner do not want to keep) and regulation states that this can be discharged to the sea but not before using an oil- water separator. Some unscrupulous bunker barge operators do a deal with bunker supplier, take the residual fuel and mix with the legitimate fuel. Similarly, vessels still dump this residue in the sea. But, the problem is finding which vessel has been doing this.

BunkerTrace developed a synthetic DNA (an oligonucleotide) to mark the fuel to address the above problems. The oligonucleotide by its nature will gravitate to water. Bunkertrace, therefore, had to change it to hydrophobic. They can now 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 can do spot checks. They take a sample and analyse with on-board computer and that will tell them whether the fuel matches the quality, which 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, which is derived from a master key and 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 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- Co-Founder of BunkerTrace.".* Sample of fuel is 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. Hence, the rationale for using blockchain can be explained using a quote from the Technical Architect at Bunker Trace "*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 cetralised 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 anonymized based on company request) is an online marketplace designed to bring together buyers and sellers in the aerospace industry from around the world intuitively and easily. For the platform, AviationSpares is leveraging blockchain to verify that the quality documents and images match the specific part offered for sale. Used aerospace parts is a $5 billion a year industry with minimal online trade. Numerous emails and phone calls along with paperwork were used to close a transaction. The combination of high dollar transaction and safety of parts to be reinstalled back into an aircraft are the two reasons 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 others 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 change five or six owners. Thus, tracking maintenance documents and passing it to other parties becomes an error-prone process and is thus prone to malpractices violating procedures outlined in manuals and the Federal Aviation Regulations.

AviationSpares requires price, product images, and quality documents for a product to be listed for sale. This ensures high quality standards with all purchased products having their associated quality documents. Equally, AviationSpares is setting some of its protocols for the industry as it builds a record of an aerospace spare part via its serialised number. All events related to that serial number is logged and recorded on-chain so that any prospective buyer will have access to all of those events. The Blockchain-Enabled platform provides part pedigree information i.e. history of usage of the part, includes images and quality documentation. It ensures no ghost listings i.e genuine sellers who are the rightful owners of the parts and not other intermediaries. The platform is also easy to use and the buyer can checkout online efficiently.

Characateristics 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. It has to be permissioned so that it is only between ecosystem players for retaining the privacy of the participating players. As the entire trace is available, the ledger is open for auditing. Blockchain adds credibility to the solution and lends value and thus helps in differentiation. It is an integral part of the offering. It is adding a big 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 specifically asked questions related to the agency factors in the legacy supply chains before blockchain implementations and characterize the coffee, bunker fuel, recycled plastic and aviation spare parts from the agency factors.

5.1 Agency factors in the studied supply chains

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 till the Freight –on Board (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."*

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 the spare parts meeting all regulatory and safety requirements. The intermediaries in the coffee supply chain such as the cooperative, the miller or the exporter had limited incentive to adequately pay the farmers.

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"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 prioritized 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."*

Risk aversion of suppliers

The risk aversion in the bunker fuel supply chain was low and the suppliers were willing to take risks by engaging in unscrupulous practices. Risk aversion in the coffee supply chain is moderate as the intermediaries have some risk of losing business as well as the risk of disturbing their long relationship with the 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.

Length of relationship

The length of the relationship between coffee farmers and intermediaries is for centuries across generations, and the farmers had almost accepted that they would be paid even lower than the 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 supply chains, the length of the relation between the buyer and the recycler was short as the buyer could 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.

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, moderately difficult in the coffee and bunker fuel supply chain as quality depends on multiple factors and 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 optimize 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 type of plastic can be provided but not very detailed instructions as quality and source of the plastic available to be collected can vary widely.

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 they deserved. *"When a farmer sells coffee that isn't fully processed (i.e, in 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 very difficult to ascertain the quality of the fuel on-board the ship. Outcome measurability in the recycled supply chain was also difficult as it was difficult to measure the quality at collection and across the recycling processes but outcome measurability in the aerospace spares supply chain was relatively easy due to well-defined quality parameters and air-worthiness requirements.

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 not worthy because of either missing records or after further testing or involvement of intermediaries. Outcome uncertainty in recycled plastic supply chain was moderate as quality fluctuations were not severe.

We characterise the supply chains before blockchain implementation in table 3 below:

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 the vessel operators)	Dependent on the value of the 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

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

5.2.1 Incentives for adoption and outcomes obtained - iFinca

When a farmer sells coffee that isn't fully processed (i.e, in 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

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

this constantly changes. But, producers are paid for their coffee in the local currency. However, 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. The café owners can improve the brand image by providing opportunities to its customers to know the farmer and the price paid to them and thus provides the cafes to engage with the 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 farm-gate price – offers buyers a level of transparency that they can rely on to source coffee that's 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 "Meet the farmer" app by which customers at the café can scan QR code and a page comes up which gives the customers the information about the brand, purchase date, global market price on that day, price paid to the farmer, farmer, farm name, farmer photos, size of the farm, and certificates. Thus, the information asymmetry in the coffee supply chain has been significantly reduced due to BT implementation.

Because of iFinca's BT enabled platform, the coffee farmers are getting paid a lot better now – 20% above the cost of production. Now with 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. 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]*.

[6] https://perfectdailygrind.com/2020/04/how-does-exchange-rate-fluctuation-affect-coffee-producers/

Farmers also dont need a loan anymore where peviously millers were giving 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. For example, a café owner in New York said. "*iFinca gives extra support for customer engagement- we got another thing to talk to customers. Coffee is a doorway to many things. Customer is able to engage in a whole new way. We got wonderful reaction from customers*. *We participate in a farmer's market in New York and people were intrigued to know about the farmgate price.* As all players in the coffee supply chain obtain some benefits, it minimizes chances of goal conflict as people who do not join risk losing business and long term relationship.

5.2.2 Incentives for adoption and outcomes obtained - PlasticBank

The end user companies have ambitious targets of using recycled materials by 2030 but there is limited global capacity to recycle plastic. Hence, these companes want to be assured of supply of recycled plastic and wants visibility that the material supplied is indeed 100% recycled plastic. Hence, these companies have high incentive to join and fund Blockchain implementation in the recycled plastic supply chain. The plastic waste collector has poor quality of life. An organized 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 organizing 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."- Plastic Bank's co-founder*.

It also made a difference to the lives of the plastic collectors. It helped in dignifying the recycling ecosystem. They received more money while Plastic Bank ensured that they have a life beyond recycling by providing pension benefits and career training. For the fisrt time in their lives, they had ability to save and get to the next stage of life. Often, women are hired to run our collection centres. A woman who has a digital account can have a huge advantage as she now has ability to control her finances. Thus, providing benefits across the supply chain reduced the goal conflict.

5.2.3 *Incentives for adoption* and o*utcomes obtained - BunkerTrace*

Vessel owners face damages to the engines resulting in breakdowns, grounding of the ship and significant revenue loss. They have to cover themselves from the above 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 in the ocean. Hence, tose 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 have incentive to join as partners but if more vessel owners adopt the solution and refuse to deal with certain bunker barge operators, then those barge operators will stand to lose business. The insurers wil satnd to gain by redcuing their costs and can offer discounts to vessel owners, who adopt the solution.

BunkerTrace's synthetic DNA to mark the fuel , ensuring traceability from the refinery to the ship on blockchain and an application to do the spot check on the ship 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 also be penalized or if they have been falsely penalized, they can prove their innocence. Key refineries are also looking to create a reputation of a perfect fuel supplier- with high quality and sustainability and BunkerTrace can validate the quality of the fuel they are supplying. The technological solution of the DNA marker and the Blockchain minimizes information asymmetry and provides full traceability of the fuel from the refinery to the ship where it is used. This avoids 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 till it is repaired. Indirectly, the risks for the insurance companies which insures the ships, are also reduced. BunkerTrace system does not remove any intermediary but it promotes fair practice in the bunker fuel supply chain. It doesn't reduce goal conflict yet unless a critical mass of players in the supply chain adopt it.

5.2.4 Incentives for adoption and outcomes obtained -AviationSpares

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 the information asymmetry. Thus, they can also reduce manhours verifying documentation and complete a deal much quickly. Thus, buyers of aviation spare parts have all the incentives to join the platform. The sellers who want to deal fairly and want to have access to large number of customers will also like to join the platform.

The platform ensures that no spurious sellers exist in the platform and hence the risk of transactions involving such sellers are eliminated. It also helps in reducing risks of human errors in checking cumbersome maintenance documents of aviation spare parts. Buyers of aviation spare parts have access to transparent and trusted information to make their decisions faster, which is 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 2000 people from 750 potential buying companies. 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 the 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 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 supplier/farmer, and adapting 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 the customers and minimizes risks of poor quality and adulteration. Such visibility for example of the farm-gate price and other data enables iFinca's customers not only to be sure of the quality but also ensure that the farmers are paid adequately. iFinca offers a QR code called Coffee Chain,which follows the coffee from the farm to the cafe. This is an encrypted QR code and only the people involved with that coffee in the supply chain have access to all the data such as farm-gate 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. 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, their 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 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 Bunker Trace stay in forever if the oil has been marked. If it comes from a refiner which has installed their tag, then BunkerTrace can track it. The Bunker Trace 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 minimized."*

5.3.2. Developing customsed and secure payment systems

Digital payment system or instant payments are key to the success of the blockchain-based platform so that the sellers can get 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 thing 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 token 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 wallet on a Blockchain platform also ensures the security of the system. The benefits of such digital payment systems for collectors is significant. For example, a woman recycled plastic collector in Haiti is an illiterate widow with 7 kids. "*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-kilogram 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 supplier or farmer 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-kilogram 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, 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 than what iFinca team thought and that was 100% better. *"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 to use the wifi before they could implement their system. *How it will 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 blockchain technology service provider can deploy are involving locals and building local relationships, educating the customers, and engaging the 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. He said "*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 build a relationship with players from the existing plastic recycling eco-system and involves them or builds a new eco-system 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 the customers

We learnt from the interview with the interviewee from BunkerTrace how avoiding the misconception of customers and educating them 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. Amount of product we use is less than 2 feet 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 the 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 "Meet the farmer" app by which customers at the café can scan QR code and point a phone camera. Thus, the customers the 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 user-friendliness of the platform and paid particular attention to consumer portal like look and feel to engage better with sellers and buyers. *"Millenials 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 analyse the roles of the different outcome and behavioural mechanisms in improving social sustainability and in reducing risks. Our analysis of iFinca and Plastic Bank cases show that customised, secure and transparent payment systems are needed so that the supplier or farmers get the benefit of the 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 (coffee and recycled plastic) 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 length of relationship. In such contexts, while working with the 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 a farmer as the information asymmetry was high and farmers had no information about the downstream supply chain. It also engaged in customer engagement so that both the end customer and the farmer could know each other while Plastic Bank empowered the plastic collectors to use recycling as a way to get to the next stage of life and invested in providing 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 seizing assets of people unfairly and can hold the corrupt accountable for their misdeeds. It can help in 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, behavioral 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, given below:

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

P1b: The relationship between adoption of Blockchain, outcome and behavior 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 supplier.

We illustrate the proposition 1 in the figure below

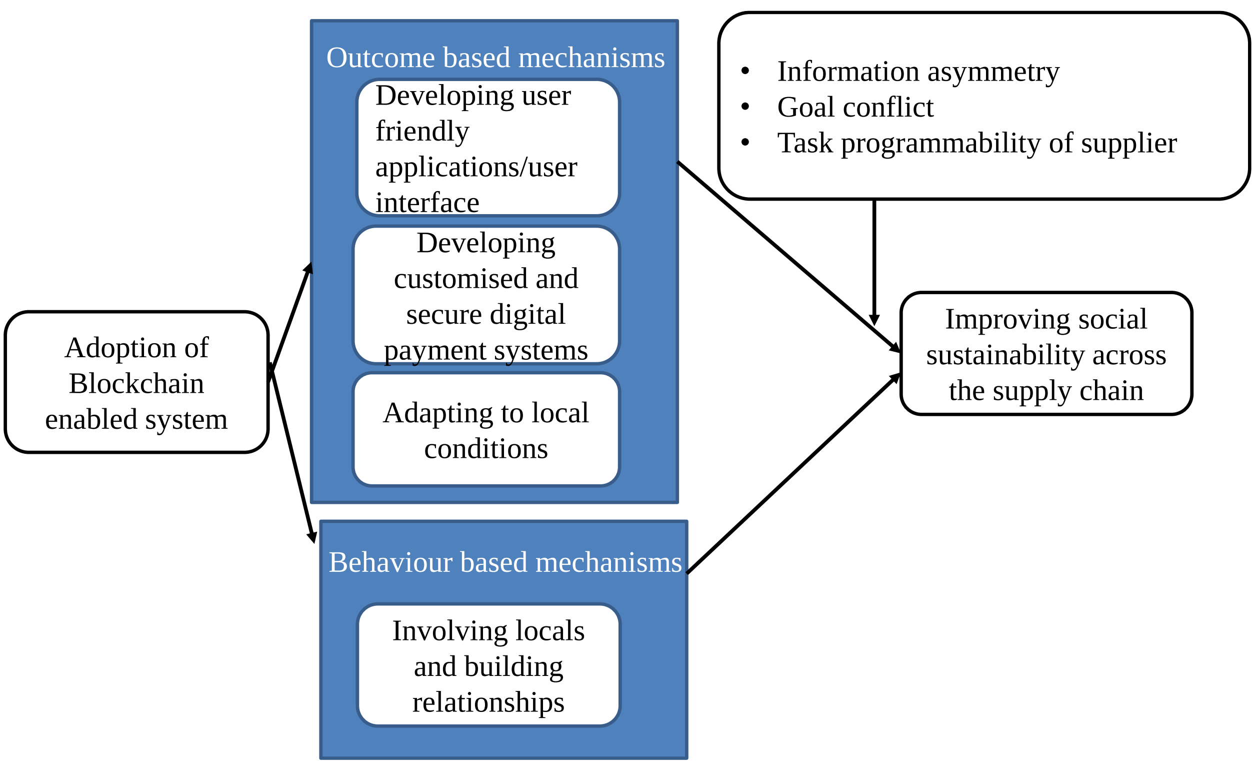

Figure 1: The role of outcome and behaviour based mechanisms in improving social sustainability in supply chain

BunkerTrace and AviationSpares cases demonstrate that implementing the blockchain enabled tracking and tracing systems can directly help in minimizing supply chain risks. BunkerTrace solutions helps in avoiding fuel quality risks for the shipping company, which in turn avoids risks of idling of the ship due to damaged engine and the huge financial risk associated with it along with the risks for the insurer. AviationSpares also help 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 uncertainty and outcome uncertainty while demonstrating different characteristics in terms of other agency factors. As outcome measurability is moderately difficult in bunker fuel supply chain while it is relatively easy in aviation spare parts supply chain, customer education and removing misperceptions about the benefits of track and trace technologies assume more prominence in bunker fuel supply chain while customer engagement through the better user interface is more relevant for aviation spare parts supply chain.

BT provides transparency and can potentially remove intermediaries from transactions and hence can mitigate 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 (Zzsidisn and Elram, 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, given below:

P2a: Adoption of Blockchain-enabled system will have a direct effect on reducing quality, financial and human error- risks in the supply chain and will alsorequire the use of outcome-based

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mechanisms such as the development of user-friendly application or user interface, adapting to local conditions and behaviour-based mechanisms of customer education or customer engagement.
P2b: The relationship between adoption of Blockchain, outcome and behavior based mechanisms and risk reduction in the 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.

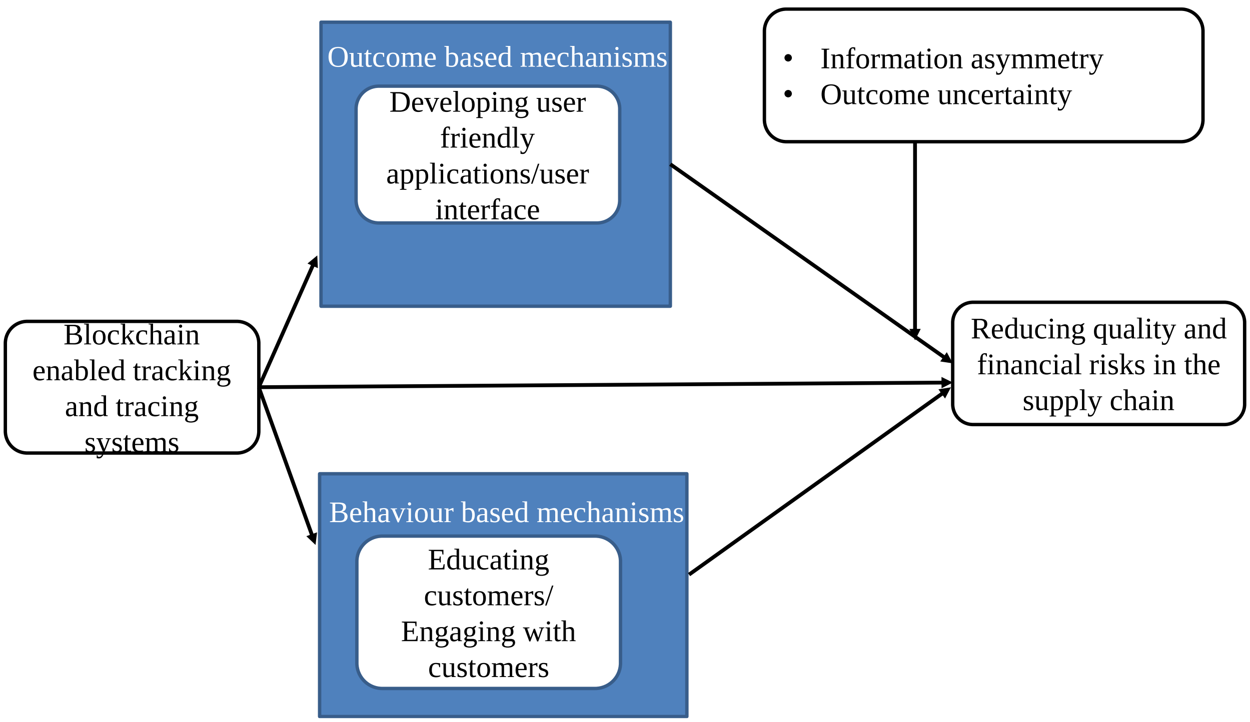

Figure 2: The role of outcome and behaviour based mechanisms in reducing risks across the supply chain

6. Conclusion and future research opportunities

6.1 Summary of fndings

Improving social sustainability and minimizing risks 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 implementation of blockchain-enabled track and trace systems can directly reduce risks in supply chain 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 application or interface, developing customized and secure digital payment systems, providing technical support for suppliers, adapting to local conditions, involving locals and building relationships, educating customers and engaging with customers. The results demonstrate how the 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 to reduce risks 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 to 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 technological solution alone may not address the problems faced in practice unless the suitable outcome and behavior based mechanisms are put in place. Our research contributes to that and will make BT service providers aware of what are needed to achieve the desired outcomes from the Blockchain implementation. The role of the mechansims will vary depending on the desired outcomes and on the agency characteristics of the legacy supply chain such as information asymmetry, goal conflict and task programmability of supplier for social sustaimability 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 and 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 mining or diamond mining which provides traceability solutions for the customers and provide social sustainability benefits to the people involved in 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 the 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 different mechanisms and different performance outcomes of BT projects can also be explored in future research.

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Appendix: 1st order and second order codes

1st order code from the case documents	2nd order code	Type of mechanisms
A QR code which follows the coffee from fam to cafe	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 price		
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 able to engage with the app in a whole new way		
Communicating how the system works with all partners	Educating the customers	
Changing the perception of customers through educational programme		