Implementation of blockchain-enabled supply chain finance solutions in the agricultural commodity supply chain: a transaction cost economics perspective

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Abstract

Agricultural commodity supply chains are characterized by the involvement of multiple intermediaries, lack of access to finance and poor financial conditions of farmers. Additionally, there exist numerous inefficiencies and a lack of transparency in the trading processes. Blockchain-enabled supply chain finance (SCF) solutions can potentially help to overcome these problems. However, there is limited research on the process of developing and implementing such solutions and the potential consequences of their implementation. In this paper, we apply the Context-Intervention-Mechanism-Outcome (CIMO) framework to systematically analyze case studies of four firms that have developed blockchain-enabled SCF solutions in agricultural commodity supply chains. The findings show that blockchain-enabled SCF solutions can reduce different types of transaction costs such as costs associated with information search, negotiation and contracting costs, and costs of accessing finance. The solutions designed with the core objective of improving the financial conditions of farmers will differ from those with the core objective of reducing process inefficiencies. The findings of the study will benefit companies planning to develop and implement blockchain-enabled SCF solutions, by highlighting operational challenges and offering concrete solutions on how they can be overcome.

Keywords: Blockchain, supply chain finance, agricultural commodity supply chain, Transaction Cost Economics, CIMO analysis

1. Introduction

During recent years, technologies related to "Industry 4.0" (also known as "fourth industrial revolution") have provoked disruption in firms around the globe (Ertz et al., 2022; Queiroz et al., 2019), and opened opportunities for firms to implement new business models (Cimini et al., 2017). Industry 4.0 comprises of numerous novel technologies such as the Internet of Things (IoT), cloud computing, blockchain, and cyber-physical systems (CPS) (L. D. Xu et al., 2018), and can to lead to improved market and environmental performance (Kumar & Bhatia, 2021; Tortorella et al., 2022). In this regard, blockchain is emerging as one of the key technologies with the potential to bring a rapid change in areas such as manufacturing, transportation and logistics (Huang et al., 2022; Kamble et al., 2019; Pournader et al., 2020; Rejeb et al., 2021; Wang, Han, et al., 2019; X. Xu & He, 2022). The key benefits of blockchain, independent of the idiosyncrasies of a specific implementation, include transparency and traceability of goods, increase in trust among the supply chain entities, improved efficiency and reduction in overall costs (Anastasiadis et al., 2022; Kshetri, 2018). Blockchain can also be used for tracking financial transactions, managing bank guarantees, and tackle fraud (Guo & Liang, 2016). Additionally, it can improve the security and efficacy of transactions in a supply chain, thus ensuring cost-efficiency and speed (Korpela et al., 2017).

Supply chain finance (SCF) is a term used for services that provide finance to different supply chain entities, thereby supporting the capital movement in a supply chain (Pfohl & Gomm, 2009). In a nutshell, it "*aims to optimize financial flows at an interorganizational level* (Hofmann, 2005) *through solutions implemented by financial institutions* (Camerinelli, 2009) *or technology providers* (Lamoureux & Evans, 2011). *The ultimate objective is to align financial flows with product and information flows within the supply chain, improving cash-flow* *management from a supply chain perspective*" (Gelsomino et al., 2016, p. 348). SCF has gained increased consideration during recent years as it can help to tackle challenges associated with determining the quantity of trade credit, credit ratings, and transactions between trade credit and bank credit (Shi et al., 2018).

Blockchain implementation can support SCF through efficient solutions pertaining to factoring, bill of lading, and reverse factoring (Hofmann et al., 2018). The technology can also support in building financial platforms in a supply chain, which helps to address the issue of insufficient sharing of data. Therefore, blockchain provides a suitable environment in which transactions can be recorded and shared with the supply chain entities with the goal of improving transparency and visibility (Babich & Hilary, 2020).

In the context of intersection of blockchain and SCF, only a handful of studies have been conducted so far. For example, Choi et al. (2020) used analytical modelling approach to study the impact of blockchain on SCF issues in the context of fashion supply chains. Du et al. (2020) proposed a blockchain-based platform to address the issues of SCF. The platform addresses the issue of trust in supply chain, capital flow, information flow, and helps in the reduction of costs and provide better financial services to supply chain entities. Finally, Roeck et al. (2020) provided some empirical evidence of the impact of blockchain on supply chain transactions.

Agricultural supply chains are frequently characterized by the lack of finance for certain entities, which leads to numerous problems such as lower crop yields, suboptimal production mix, low quality produce, asymmetric price information, inadequate storage facilities, and opportunistic profiteering (African Development Bank, 2013; Chintala, 2020; Kononets et al., 2022). Additional issues that are specifically related to SCF include payment terms (payment periods and trade credits), and cash flow analysis (Choi, 2020). Blockchain implementation can bring transparency to agricultural financial transactions, credit history, and financial agreements for smallholders who want to invest in farming. Shared access and irreversible agreements can allow small farmers to pay for raw materials and machinery partially or after delivery and guarantee fair market pricing ([x]cube LABS, 2020). Therefore, blockchain is expected to play a very crucial role for SCF, particularly in agricultural commodity supply chains. In this regard, it is important to understand the implementation aspects of blockchain-enabled SCF solutions, and potential outcomes in the context of agricultural commodity supply chains. To the best of authors' knowledge, no studies exist which have specifically addressed how existing blockchain applications address SCF issues and their remedies in agricultural commodity supply chains. Therefore, this paper fills these research gaps and specifically addresses the following research questions:

1. How can blockchain-enabled SCF solutions be implemented in agricultural commodity supply chains?
2. How can blockchain-enabled SCF solutions help in reducing transaction costs across agricultural commodity supply chains?

In this paper, we address the two research questions by collecting data through semi-structured interviews from firms which have already implemented blockchain-enabled SCF solutions in their agricultural commodity supply chains. The data is analyzed using the Context-Intervention-Mechanism-Outcome (CIMO) framework. Our findings illustrate that the implementation of blockchain-enabled SCF solutions differs depending on the respective core objective (i.e., improving the financial conditions of farmers vs. reducing inefficiencies in existing processes). Managers will become aware of the operational challenges and learn how they can overcome the challenges..

The remainder of this paper as structured as follows: In section 2, we discuss the existing literature on blockchain and SCF. Section 3 presents the CIMO method and outlines our approach. In Section 4, the background of the cases is presented, and in Section 5, the CIMO analysis is detailed, starting with the context, followed by several solutions, mechanisms and, finally, the outcomes. In section 6, we discuss the results, develop propositions, outline the contributions and, finally, conclude the paper with some recommendations for future research in section 7.

2. Literature review

2.1 Blockchain technology – Overview and potential applications

Blockchain is defined as "a digital, decentralized and distributed ledger in which transactions are logged and added in chronological order with the goal of creating permanent and tamperproof records" (Treiblmaier, 2018, p. 547). Here, decentralization denotes that there is no single party that controls the processing of transactions and a distributed ledger is a multi-party database without a central trusted authority (Hyperledger, 2018). In a blockchain, all the data related to the transactions is stored in the form of blocks, which are added chronologically to form a chain (Menon & Jain, 2021). The chain is then distributed among all the participating members. Blockchain employs a transparent consensus mechanism, which guarantees that only valid transactions are executed (Bocek & Stiller, 2017). On a collaboration level, even the governance of interorganizational exchanges can be automated (Petersen, 2022).

Blockchain implementation can provide firms with several benefits. For example, it can assist organizations with conducting and verifying transactions on a real-time basis through a distributed ledger, without the need for assistance by a central authority (Glaser, 2017). All the transactions performed by a party are visible to the other parties; thereby keeping a check on any malicious actions (Naef et al., 2022; Tapscott & Tapscott, 2017). Through the reduction of necessary communication and interaction among the entities as well as the digitization of physical processes, blockchain can help in increasing the speed of execution of numerous operations in a cost-effective way (Cole et al., 2019; Nandi et al., 2020).

In supply chains, there is frequently a lack of trust between the suppliers and the buyers, which is caused due to conflicting goals and objectives (Nyaga et al., 2010). In this regard, the application of blockchain can help to record all data, which can solve disclosure issues by holding related supply chain entities accountable. This can increase trust among the supply chain members and minimize the detrimental effect of conflicting goals (Pournader et al., 2020). Thus, blockchain helps in creating a business environment which is transparent, free from intermediaries, and fosters trust among all the entities through a combination of digitization, cryptocurrencies, and smart contracts. Additionally, blockchain-enabled smart contracts can verify data within the agreements and automatically trigger payments. In this regard, blockchain can help in completing the transactions faster to pay the farmers quickly (Kayikci et al., 2020). Besides payments, blockchain can also initiate other transactions which include issuing of goods and invoices or confirming a pickup without any manual verification.

Though managers understand the potential effects of blockchain, many of them hesitate to invest in the technology due to lack of clarity pertaining to specific benefits of its adoption (Hald & Kinra, 2019). Despite its postulated benefits, the effective implementation of blockchain is accompanied by several challenges which include high implementation costs, privacy concerns, and lack of technical knowledge (Kamble et al., 2019). Additionally, academic literature on practical blockchain applications and their effect is scarce (Queiroz et al., 2019), and potential business implications are still under-researched (Treiblmaier, 2018). Thus, more studies are required for exploring and analyzing the process of developing concrete solutions (Wang, Singgih, et al., 2019).

2.2 Supply chain finance and blockchain

SCF describes "a set of technology-based solutions that aim to lower financing costs and improve business efficiency for buyers and sellers linked in a sales transaction" (Bloomenthal, 2021). It aims to optimize financial flow through solutions implemented by financial institutions or technology providers (Hofmann, 2005). Generally, those solutions are facilitated by the external entities who have expertise in providing such services (de Boer et al., 2015). SCF combines managerial, technological, and financial mechanisms for optimizing the working capital and solving liquidity issues in supply chain transactions (Global Supply Chain Finance Forum, 2016). Initially, though the orientation of SCF was primarily towards optimization of working capital, it is now also geared towards increase in efficiency and improving the collaboration among numerous supply chain entities (Caniato et al., 2019). The key objective is to align the financial flows with product and information flows within the supply chain, thus improving cash-flow management. SCF solutions can also help organizations to obtain loans from financial institutions (Ali et al., 2018). In nutshell, blockchain-enhanced SCF helps organizations to realize their financial requirements digitally, such that the transactions are visible across the supply chain.

Managing SCF involves core supply entities, supporting firms, logistics firms, banks and other financial institutions, each of the organizations and institutions playing a distinct role (Du et al., 2020). To illustrate the overall functioning, Du et al. [19] built a blockchain-based supply chain financial platform which manages the financing model, aims to facilitate trust among the participants, and ensures financial efficiency, knowledge flow, and availability of financial services.

In order to achieve the maximum benefits from SCF practices, all the supply chain entities need to cooperate with each other, which fosters low default risks, low capital costs, and new opportunities for loans (Ali et al., 2018). Thus, SCF can also enhance confidence, trust, and commitment levels among all entities along the supply chain (Randall & Farris, 2009). SCF can also be applied to address conflicts related to financial interests between different supply chain entities, and thus build a stronger relationship between them (Caniato et al., 2019).

In the existing supply chain systems, it is difficult to obtain trustworthy data, which makes it challenging to control prevailing risks. Blockchain implementation allows to record all the transactions and data, which is immutable and can be accessed and audited any time. Financial flows can be increasingly streamlined using blockchain, where all the involved partners will be able to share and monitor finance-related information such as latest invoice status, check credit limit and payment in a transparent manner. Thus, all participants can have easy access to real-time SCF information and are able to continuously monitor the flow of goods and transactions digitally (Omran et al., 2017). In this regard, blockchain-enabled SCF solutions foster the creation of accurate and trustworthy information, which can aid financial organizations to examine the creditworthiness of their clients, and decide whether to issue loans or not.

Despite the discussion of these potential advantages, research in this field is still quite limited (Caniato et al., 2016; Hofmann & Johnson, 2016). Specifically, empirical research examining the use and applications of blockchain for SCF is missing in the literature (Wang, Han, et al., 2019). Therefore, there is a need for rigorous academic research that can improve the understanding of how blockchain can address challenges associated with financial transactions across multiple entities in a supply chain. In particular, the question of how blockchain solutions can be designed to reduce transaction costs has been identified as a promising research opportunity by Treiblmaier (2018). To answer this call for research, in this paper we analyze how blockchain-enabled SCF solutions can be implemented in practice and how these can reduce transaction costs in agricultural commodity supply chains.

3. Methodology

3.1 Multiple case study approach

We used a multiple case study approach for collecting the data for our study. Case studies are an established method in operations management, specifically in complex contexts, for developing new propositions, theory building, and to interpret particular situations (Childe, 2011). Specifically, case studies can help in understanding the problems in industries, implementation of new technologies, and operations design (Childe, 2017). A case study method is also considered as appropriate for exploring poorly understood phenomenon generating new knowledge (Stuart et al., 2002). Multiple case studies allow researchers to perform cross-case analysis and identify patterns among the variables of interest (Eisenhardt & Graebner, 2007). In comparison to a single case study, multiple case studies foster comprehensive and complete understanding of specific contexts (Yin, 2013). From a methodological standpoint, case studies increase robustness of results and reduce the risk of observer bias. Our research purpose is to observe and understand the phenomenon in its actual contextual setting (Yin, 2013), and develop relevant insights for blockchain implementation for SCF. Thus, a multiple case study is an appropriate method for achieving the desired objectives.

3.2 Data collection

To collect relevant data for this study, we screened news articles in Factiva (a business information and research tool from Dow Jones & Company), about organizations that have developed blockchain-enabled SCF solutions in the agricultural commodity sector. By using the keyword combinations "blockchain" and "finance" or "blockchain" and "supply chain finance", we identified 19 relevant companies and contacted senior professionals working in those companies through LinkedIn and by contacting the organizations through email. We explained them the research objective and asked for their interest for an interview with our team. In total, 4 companies qualified for the research objectives of this study and key informants from these companies agreed to participate (Company A, Company B, Company C, and Company D). All of these companies started their blockchain operations in recent years and classify as small companies with less than 100 employees. In all of these cases, blockchain-enabled SCF constitutes a core component of their agricultural commodity supply chain. In line with the previous studies, data from four companies is ideal for a multiple case study to ensure a sufficient depth of coverage while ensuring diverse opinions (Bressanelli et al., 2019; Cao et al., 2013; Farshidi et al., 2020; Gunasekaran et al., 2018; Lage Junior & Godinho Filho, 2016).

The interviewees are senior professionals, actively involved in the blockchain implementation projects and possess a detailed understanding of blockchain-enabled SCF solutions. Prior to the interviews, they were sent a brief note on the objectives of the study and the interview protocol, which is provided in the Appendix. Semi-structured interviews were conducted with these professionals. During each interview, all the researchers involved in the study were present and took notes to avoid bias caused by the coding of individual interviewers (Eisenhardt & Graebner, 2007). Each interview was recorded with the consent of the interviewee. We prepared the transcript of each interview and conducted an in-depth analysis of each case. We re-read the notes of each interview several times to examine the whole context in detail. Two researchers independently identified the contexts, interventions, mechanisms and outcomes from the interview transcripts and the analyses were then discussed amongst all researchers involved in this study. The interview transcripts along with the CIMO analyses were shared with the interviewees for validation. The findings, propositions developed and the frameworks were validated with the interviewees, which ensured reliability. The use of triangulated data, case study protocol and review of the interview transcripts ensured construct validity. The use of cases for different types of SCF applications, use of knowledgeable respondents and pattern matching amongst the cases ensured internal validity. The use of multiple case study approach and considering the context of the cases for our analysis ensured external validity. The details of the same are provided in Table 1.

Table 1. Validity and reliability criteria --- about here

Following the recommendations from the literature, our study uses multiple sources of data to triangulate, validate and cross-verify of findings (Yin, 2013). In addition to the semi-structured interviews, we collected additional material from the websites of these organizations, news articles and other relevant documents sent by the interviewees. Table 2 summarizes the details of the conducted interviews.

Table 2. Overview of the conducted interviews and secondary data collected --- about here

3.3 CIMO analysis

The critical evaluation method and the CIMO framework from Pawson and Tilley (1997) is used to systematically analyze the interview transcripts. CIMO logic describes "what to do [Intervention], in which situations [Context], to produce what effect [Outcome] and provides an understanding of how the intervention generates the outcomes [Mechanisms]" (Denyer et al., 2008, p. 396). The CIMO logic is frequently used in the design science (DS) literature with the intention to generate knowledge that can be applied for designing and implementing processes, and activities for achieving the desired outcomes (van Aken et al., 2016). CIMO follows an exploratory, rather than an explanatory approach to a problem and involves various stages (Holmström et al., 2009), consisting of the solution incubation in which a potential solution for the problem is developed, solution refinement in which the initial solution is evaluated and refined through iterations followed by establishing its theoretical relevance and explanation using formal theory. Figure 1 outlines the respective components in the context of our study.

Figure 1. CIMO framework for agricultural supply chains --- about here

4. Background of cases

Company A creates the connection between financial institutions and agri-businesses through a digital infrastructure that directly links agri-trade activities with financial services. Agri-businesses use Company A to manage their entire business and trade operations in one place including contacts, invoices, purchase orders, and payments. Financial institutions use Company A to get the transparency and infrastructure necessary for providing financial services to an untapped agricultural market. Company A Finance enables agri-businesses to access services from financial institutions such as applying for working capital, loans, insurance directly on the platform.

Company A was born in the minds of two cousins that grew up in agricultural communities: "As sons of third-generation farmers, we worked closely with farmers since childhood […] We know how it feels to work in the fields from dawn to dusk and then sell our products without making enough profit to run a sustainable business. This is the reason that we built Company A - to empower agricultural producers worldwide to trade directly with their buyers and help them to create and maintain a sustainable business."- Company A co-founder.

Company B powers the tokenization of agriculture commodities making them tradable and financeable on the blockchain. It has developed a marketplace connecting end-buyers and end-sellers of commodities. It also gives farmers and Small and Medium Enterprises (SMEs) access to financing through lending on its platform.

Company C provides a blockchain-enabled trading platform that allows participants in the agriculture businesses to trade and perform transactions with unknown parties with higher level of certainty. Company C leverages blockchain to further ensure data integrity and authenticity for all the parties involved in a trade.

Company D provides small farmers with access to capital at an affordable interest rate through its financing platform. The platform links small farmers with the funders, who make investments and fulfill the financing needs of the farmers. The platform is useful for small coffee farmers, specifically in poor regions, who do not have access to resources from banks.

In the context of this research, we refer to a farmer as someone, who owns pieces of land and is involved in growing agricultural produce such as cereals, fruits and vegetables. In our study, we did not include companies who deal with poultry farming, other meat products or dairy farming.

It is important to note that Case companies 'A', 'B' and 'D' specifically deal with farmers as well as others involved in the agricultural supply chain such as traders, while 'A' also deals with financial institutions such as banks. Company 'D' primarily deals with small-hold farmers, who have the require for funds, while others do not have such restrictions and also work with farmers who own large tracts of land. Case company 'B' does not directly deal with farmers but with grain traders. We also like to draw attention to the fact that farmers are not necessarily the entity which is bearing the cost of the blockchain-enabled solutions. For company 'A', it is the banks, for company 'B' it is the buyers (typically food companies and retailers), for company 'C' it is the cereal traders. Company 'D' is unique as they are opening their platform for individuals seeking to invest their funds for specific needs of farmers and, as investors make profit through their investments, they also pay some fees to the platform.

5. CIMO analysis of the cases

In this section, we analyze the cases following the CIMO framework and investigate the context for blockchain-enabled SCF implementations, the incubation of the initial solution, the solution refinement, and the mechanisms linking the interventions to the obtained outcomes. We present the main topics that emerged during the cause of our analysis pertaining to the respective sections of the framework.

5.1 Context for blockchain-enabled SCF implementations

5.1.1 Liquidity problem for farmers

Farmers face liquidity problems throughout the crop cycle. They need to buy seeds, fertilizers, and pesticides. After they sell the produce, it takes around the months for them to get paid. Company A report that, on a worldwide basis, farmers require funding of around 450 billion USD every year. However, they only receive a little less than 10 billion, which means that, compared to actual demand, the actual supply is less than three percent: *"25% of the global population of the world population are unbanked. They don't have access to the financial assistance." – Company D manager*

The farmers also have to ask for loans from their communities, which is not easy to obtain, as there is regularly a shortage of cash. Still, in case the farmers are able to get cash, they have to pay usurious interest: *"The money is so expensive that these people are paying interest rates over 100% per year" – Company D manager*

5.1.2 Lack of digitization in the agricultural supply chain

Multiple players are involved in an agricultural supply chain. These include farmers, traders, those involved in storage of cereals and fruits and vegetables as well as logistics companies. Currently there exists a limited amount of digitalization in the agricultural supply chain resulting in lack of transparency. Most of the processes in the investigated agricultural supply chain are manual with limited use of digital technologies. "*The players in the agricultural supply chain […] did not have any digital records. All transactions were manual." - Company A Co-founder*

5.1.3 Banks' limited business in agriculture sector

Banks have historically done minimal business in the agriculture sector due to lack of information about farmers and the quality of their produce: "… *for a leading bank we found that within their entire portfolio, only four percent goes to agriculture, though the 30 percent of the entire country's GDP is agriculture. So, it didn't make any sense."- Company A Co-founder*. The current lending process followed by the banks is determined by manual processes and, on average, banks are reluctant to lend to small farmers: *"The whole lending collection process is manual. This involves a lot of like a paper based documentation and lot of human resources are involved."- Company B Co-founder*

5.1.4 Grain trading over phone

The agricultural commodity trading is done using inefficient brokerage processes, which is frequently conducted over the phone. These procedures create multiple problems when closing a deal: *"A seller or a buyer call a broker who will call potential buyers and sellers and will try to come with a discussion on price, quality, delivery date etc. The Problem with phone-based dealing is that the parties may not meet deadlines. They don't come back until few hours and lot can change in that period." – Company C COO*

5.1.5 Limited markets for the farmers

Farmers frequently have limited markets to offer their produce, as they are only able to sell it in local markets. Consequently, they are not able to get a price that is in accordance with the quality. Therefore, they are only just able to pay off their loans, but lack a fair profit: *"The other problem that these farmers had is that they sell their crops in a very local market and the total market cannot pay an excellent price for their product" – Company D manager*

5.2 Solution incubation as the intervention

5.2.1 Acting as a digital broker

Company A decided to create a reputation system, which allows farmers to transact without fear of unfair treatment. The initial pilot project in Rwanda was tested with coffee farmers, who were able to communicate with new buyers or market their produce by a simple matchmaking system: "*We understood what farmers had to offer and what the buyer wanted to buy and created a match between them. Later on, we realized that by doing that, we were just replacing the broker with a slightly smarter broker, but we were adding additional costs*." Company A realized that though they addressed the trust issue, it turned out to very difficult to scale this system as they were taking an existing process and automating it but without much additional value.

5.2.2 Tokenization of warehouse receipts and execution of smart contracts

Company B tokenized warehouse receipts for commodities and the cash which the buyer has with the bank and swapped the tokens to execute the smart contract. This ensures that the buyer gets access to the commodities and the seller is paid: *"Small agricultural SMEs get the produce from multiple farmers and deliver to the warehouse, belonging to a commodity exchange. The exchange verifies the quality and quantity of these commodities and issues a warehouse receipt, which is a tokenized asset on our platform"*. One important part of this process is the tokenization of assets, which ultimately facilitates their transferability: *The buyers connect with partner banks and can top up their wallet on the platform. And then upon signing the transaction, everything moves on to the blockchain. Then a swap is made so the buyer ends up with a commodity token, which they can redeem in a warehouse or trade on to another buyer, and the seller can redeem the money token into the bank account and encash it"*.

Company C uses a state-of-the-art cryptographic hash algorithm to secure a single version of the cargo documents via blockchain, guaranteeing all parties in the trade have access to its documentation. The smart contract is time-bound and the platform includes an execution module that executes the commodity trade using the provided e-template. Both buyers and sellers have the option of recording the document hashes on blockchain as well: *"The parties have been able to record all actions from negotiations to concluding the contract and all execution steps and cargo docs, and sign them with advanced e-signatures on a public blockchain"*.

5.2.3 Connecting lenders and farmers

Company D built a system which connects people interested in lending money with the farmers who need money. Investors lend money to the farmers, which is then used for producing coffee. The core feature of the new solution is the matchmaking which benefits both parties: *"A quarter* *of the world's population is unbanked and don't have access to the financial system and in the other parts of the world, money is so cheap that people do not get any income for savings in banks. So we built a technological bridge between these two worlds and made the one the solution for the other".* People who have invested get their money back with substantial interest rates they are not able to earn with other investments: *Then, they give the lenders back the money with an interest rate, which is around 15%. Thus, we are giving the farmers a new financial tool with a low interest rate and people lending from all around the world can earn a profit for their savings".* Further, Company D is also able to sell the coffee at the higher prices in the international market, as the coffee is of high quality: *"We take their coffee to international markets. The coffee is so good, so we are able to sell it at a price which justifies its quality*".

5.3 Solution refinement to improve the intervention

5.3.1 Change of operating model

To be able to create that ecosystem, Company A understood that working with the farmers alone was not enough. The farmers need funds and banks are interested in funding these farmers. So, there was a need to gather the information from the trading platform and feed it directly into existing bank infrastructures: *"From the initial specific use case in Rwanda, we understood that the objective should not be to become a commodity broker, but an information broker between the farmers, their buyers and the bank.* Another key issue was to focus on the relations and to strengthen them by improving the overall information flow: *"And we skipped on the entire matchmaking solution to focus more on taking the existing relationship, digitizing it, giving it an identity*".

5.3.2 Development of technological interfaces for banks and inclusion of financial services capabilities

Company A developed a so-called USSD (Unstructured Supplementary Service Data) interface, which enables communication with the platform through text messages. They include two types of applications - a mobile and a web app, which they can use to access and manage their communications. In addition, a third interface allows banks to access information directly from the platform. They also developed a software development kit that integrates its solution into any existing platform. Finally, to keep track and to create those identities, they deploy a blockchain component, which works as an immutable ledger for all the transactions. Not only the transactions, but also personalized crop-related information from farmers and ratings from buyers are recorded. Thus, Company A created a reputation system on top of a blockchain ledger.

5.3.3 Minimal viable experimentation

Company A actively followed an agile minimum viable experimentation approach to develop solutions, and obtain feedback to further improve it: *"Our philosophy is to create a version and release it, see the feedback, see what's working, what's not working, and iterate. It's called Minimal Viable Experimentation (MVE). And then based on the feedback from that specific experiment, we decide if we implement the solution or not". – Company A co-founder*

5.3.4 Customizing to the local requirements

Based on published research, Company A understood that a significant percentage of Kenyans use smartphones. So, they created a mobile app, but they failed to realize that although people have smartphones, they don't necessarily use them. Thus the mobile app, which they initially developed was not a viable solution as their targeted clients were not able not use it: *"The* *feedback that we received from the bank was that the Agri SMEs were using the platform, but we didn't see any farmer activity at all. So immediately, we started working".* In order to better understand the reasons for the lack of adoption, they did some field research: *"We went to Kenya, spent some time there, and after a month of actually being in the field, we saw that everybody had their old phones or the feature phones. They communicate with the multiple services using USSD, which is basically text messages"- Company A co-founder*

Based on the feedback received from the bank and the information gathered during their field visits, Company A decided to implement a solution that has the ability to communicate with the platform through text messages. This allowed banks to receive information from the farmers but they also figured out that the farmers also needed access to financial services. Hence, Company A implemented a blockchain-enabled solution that ensured the trusted and secured information flow and made the financial services more accessible to the farmers. They also found, that, in general, it is very difficult to approach farmers directly since they are frequently suspicious because their relationships with outsiders or with brokers is often not good. So, Company A understood that if they approach farmers with a well-known contact person and if they bring value to everyone, then it would work. Similarly, some of Company C's big customers have demanded to provide them a customized version of its marketplace for their local markets and tenders, and the company is currently working on satisfying those needs.

5.3.5 Offering a portfolio of solutions

It was difficult for Company B to implement their solution because Nigeria's commercial lending rate was at twenty-four percent. Producers incur substantial production and transportation cost and have to borrow at a high rate. This makes investments very prohibitive because the primary commodities also have low margins. Therefore, the aggregators and SMEs face lot of risk. In order to solve this problem, Company B went on to discuss with the banks a preferential rate for the SMEs. Since the banks were not convinced, Company B had to develop alternative solutions, which can equally appeal to the banks, the buyers and sellers: "*We developed other solutions like supply chain finance, a software-as-a-service for banks, which allows them to run invoice, inventory or purchase order financing programmes. Currently, the bank has no way to track whether the invoices exist or whether those are duplicated, or have been settled or not. Now we resolve this by developing an end-to-end process". - Company B Co-founder.* In this regard, the offering of new options led to the redesign of processes and the establishment of trust: "*So we can set up supply chain programmes with a bank and with big corporates, who can send purchase orders to the trusted suppliers. The bank then lends based on these purchase orders to these SMEs. There is no interest for the suppliers to cheat because then they will lose a big client. And, bank has the confidence in such a company with triple-A credit rating that they will be able to pay back". - Company B Co-founder*

Company C also added an additional service in terms of on a non-fungible token (NFT) for grain export. Company C, together with Grupo Ceres in Mexico created the world's first grain NFT on an export port terminal. In doing so, 30,000 tonnes of white corn were tokenized, which ensured that a digital representation of the cargo fitted to its specific characteristics has been created. Thus, the token replaced the terminal's paper receipt.

5.3.6 Improving filtering criteria for deals and better visualization

The co-founder of Company C worked as a broker in grain trading industry and had lot of expert knowledge. Based on this experience, several refinement of the processes and the interfaces were established, which included the filtering of the commodities in the dashboard, the visualization of movement of the prices as in a stock market and a dark background for better visualization.

5.4 Mechanisms linking the intervention to outcomes

5.4.1 Ability to conduct performance assessment and risk assessment

Company A can offer numerous benefits to the banks as it provides an ability to conduct performance and risk assessment of the farmers: *"We have the ability to create two things: First, a performance assessment "Can this farmer perform or not?" and, second, a risk assessment, which means that we can take the entire history, based on what this farmer bought, sold and grew in the past six months, which is usually through trade cycles. It can tell you that his credit score is something around this area and he will be able to pay back or the default rate is going to be this much or that much".*

5.4.2 Hands-on ability and understanding local culture

Being present on the ground to understand the real problems is what provides Company A with a competitive advantage as they can ensure that their solution actually works at the hands of the real users: *"We spent three months in South Africa, two months in Kenya and one month in Zambia. […] Within every new market that you approach, which is not your home market, you need to have a local, who is speaking for you. We have freelancers helping us out where we don't have a team on the field there. But it's very important and necessary and that's why our solution works."*

5.4.3 Emphasis on ease of use and value

Emphasizing value to all users is a key mechanism which ensures adoption of complex technological solutions: "Making sure that people are adopting a solution is the first parameter that you need to pay attention to. The second thing is obviously increasing the value that you bring. Specifically, in African countries, if the user does not see some sort of value, the lifespan of the app is going to be short. They'll use it once or twice, but if they do not see continuous value coming from it they will stop using it."- Company A co-founder

5.4.4 Recording trading requirements and blockchain-based electronic signatures

Current grain trading process required multiple forms of documentation and deals conducted over phone. Executing a deal takes a lot of time due to substantial manual work. Company C's platform brings all grain trading functionalities in one place: *"The Company C platform created a customized execution e-template for us, exactly as per our contract terms, with all of the main details and notifications in one place and always in front of our eyes, which enabled us to effect a much more streamlined trade execution than the usual old way*," according to a trader (Bobylov, 2019). In this regard, the blockchain solution creates authenticity by ensuring that transaction can be connected to specific entities: *"Currently, we are applying blockchain for two functions. The first is blockchain-powered Advanced Electronic Signatures (AES), for which parties independently generate their own cryptographical keys. Then they sign with that AES all the firm bids & offers, contracts and main execution events"*. Additionally, the immutability of data stored on a blockchain enables new levels of trust: *"The second function is recording. All firm bids, offers, contracts and important execution events are recorded forever on blockchain. So with these two functions, AES and recording everything on blockchain, we are bringing, so far unseen, certainty - you've done the business, you are really sure you've done one. These features are great for eventual disputes, arbitration or whatever"*.- CEO of Company C ((Grigorov, 2021))

5.4.5 Secure transactions

Enabling secure transactions is the backbone for all blockchain-enabled SCF solutions. Company D, for example, has built a platform with a specific focus on secure transactions: *"You as a user* *can see in the platform that a community is asking for 5,000 euros to grow their produce. An user will invest some amount, say 100 euros from his own wallet to the smart contract. If the money is required in two weeks, and in two weeks we don't get the 5,000 euros, then the contract automatically gets cancelled and the user gets back 100 euros. Else, Company D sends the money to the local node (leader of the Community) and they change the cryptocurrency into Mexican pesos. At the end of the year, the farmers give Mexican pesos with the interest. The local node changes it into cryptocurrencies and send those to the smart contract."- Company D manager*

5.5 Outcomes

5.5.1 Change in balance of power

The solutions provided by Company A and its adoption changed the balance in power in their communities: "Usually whoever holds the money and the information, can organize the situation according to his own interest. We shifted this situation. The farmer now thinks "Now, I don't need to rely on that specific broker because I can get financial information or financial services directly from the bank and they know who I am. So I have the ability and the flexibility to work with whoever I want". Similarly, in the Company B case, the farmers can get better prices on the market: "The famers can afford to wait because they can borrow money based on the warehouse receipt token and then wait for a better price to sell so they don't have to hurry to sell them in harvest". In the case of Company D, as farmers are able to offer coffee to international markets, they have more options to sell their products and get high prices in return.

5.5.2 Upliftment of the local community

Our results reveal that the positive effects of blockchain based SCF solutions for local farming communities might reach far beyond achieving better prices: *"In one community where we* *worked with in Kenya, an entire village sell through one person that represents the village. By helping them receive financial services, and work with whoever they want to work with, we've seen a shift within the community in the sense that suddenly a new school and a small hospital was built for the community. Once you support the community financially and you show them how to do business in a more organized way, they understand how to scale up and grow."- Company A cofounder*

Company D solution also aims to address poverty and put an end to hunger by opening international markets where farmers are able to get higher price for the produce, and have to pay lower interest rates: *"The farmers are hard workers but they are not able to save anything because all their profit goes to pay interest rates. Now, we are giving them new financial tools with interest rates lower than the 25%. We are really helping them to break the circle of poverty. These people will be able in the future to develop themselves economically and socially" - Company D manager*

5.5.3 Increased deployment of financial services

Company A has opened up a new avenue for banks to distribute financial services, which poses an immediate benefit for financial institutions. Banks get business intelligence and an additional avenue to distribute their financial services. Company B has also ensured that the banks can get trusted big companies as their customers, who buy commodities using the blockchain-enabled platform. Thus, the solutions offered have resulted in increased deployment of financial services to the agricultural supply chain.

5.5.4 Efficient way of doing business and access to finance for agri SMEs

Company A formalized and simplified the business of agricultural SMEs, who buy and aggregate the produce from the farmers, who get new access to finance: *"So we took the existing processes,* *digitized them, made sure that these are very easy and comfortable to work with and gave the agri SMEs the ability to directly communicate with thousands of smallholder farmers with the click of a button and reduce their costs".* This also substantially simplified the underlying processes: *"Usually they used to have teams of eight to fifteen people, to communicate with the farmers. Now they have a single person and they can do everything digitally and the farmers can answer back by using text messages. We give them the ability to access financial services that they didn't have before".- Company A cofounder*

5.5.5 Reduced uncertainty through efficient transaction and deal process

Company B's solution improved the efficiency of the transactions and the conclusion of the deal: "The entire process is very streamlined, very simple, very efficient. And of course it saves a lot of cost and without errors as there is no need for any reconciliation."- Company B co-founder. A similar benefit was also observed in the case of Company C: "Solving a problem over phone is very difficult. The technology allows deals to be negotiated efficiently, reducing the time and costs of execution, with a detailed history of all actions and documents exchanged and traders no longer have to wait for signed paper contracts. There is significant reduction in paper work, and, you don't need a large team."- COO- Company C. An official document of Company C wraps up their main objectives: "Essentially what we've done is we have digitalized the agri-trading brokerage processes and eliminated all uncertainties."- Company C CEO (Source: secondary document shared by Company C). In a published report, the COO of Company C wraps up the main advantages: "Company C allows for up to 30% reduction in execution costs, e-templates enable traders to enforce execution with their counterparties, while even inexperienced people can now use them". Some of the offered benefits are especially appealing to business partners in countries that have specific regulatory requirements: "But the problem is parties, especially in emerging markets like Russia and Ukraine, need signed contracts because unsigned broker confirmation is enough for GAFTA but you cannot enforce it in a Turkish or Russian court. So in our platform, you can immediately sign the contract with an advanced electronic signature, so you are sure you've done the business". - CEO of Company C (source: secondary news article - (Grigorov, 2021))

5.6 Summary of the CIMO analysis

The CIMO analysis of the cases is shown below in Table 3. It illustrates that liquidity problem for farmers and exploitation of farmers by intermediaries form the context for the development of solutions to address pending problems in three of the four cases (Company A, Company B and Company D) while improving the efficiency of the grain trading process was the context for the other (Company C). The outcomes obtained included improved financial access for the farmers and an upliftment of the local communities along with improved efficiency of the entire trading process. Involving the banks as customers helped fund the deployment of the solutions and also improved banks' agriculture business. However, Company D took a different approach and ensured financing through private investors. Company A and Company B had to significantly change their initial offerings to adapt to existing requirements. Company A using their proactive, on-the ground presence to refine their solutions, which ultimately ensured its adoption. Company C had the benefit of its founders' rich previous experience and thus had to only make minor modifications to its offering to improve user-friendliness. Thus, for blockchain-enabled SCF solutions to work, it is important to understand the perspective of the users and to tailor the solutions, which provide value to them. The technological solution alone may not provide benefits unless attention is paid to the conditions and requirements of the real world. Companies have to invest in building a solid on-the-ground presence and establish relationships with the local community to ensure that their solutions get adopted.

Table 3. CIMO analysis of the cases --- about here

6. Discussion

6.1 Reducing transaction costs through blockchain-enabled SCF solutions

Blockchain-enabled SCF solutions help in reducing opportunism and behavioral uncertainty in terms of verification and performance assessment. The mechanism which helps most in reducing behavioral uncertainty is the ability to conduct performance assessments and risk assessments using the data from farmers and SMEs, which reduces search and information costs for banks and ultimately provide banks with the confidence to lend. Secure transactions prevent opportunism and encourage corporates to buy commodities using a blockchain-enabled platform, which in turn guarantees that the banks also lend to the SMEs, who are subsequently able to reduce their cost of accessing capital. Providing all functionalities in the same platform helps in reducing negotiation and contracting costs. The other mechanisms of hands-on ability and understanding local culture and emphasis on ease of use and value are behavioral in nature and facilitate adoption. We outline below the specific types of transaction costs, which are impacted.

6.1.1 Search and information costs

Banks face significant transaction costs in reaching out to farmers or agricultural SMEs as they do not have information about the farmers' productivity and their credit rating. Company A identified this need for banks to increase their agricultural business and developed a blockchain-enabled secure solution with a reputation system for farmers, which enabled the banks to have all the information and also interact using the web and mobile applications and eventually the text messaging system. This significantly reduced the transaction costs of doing business for the banks. Similarly, Company B's solution consisting of tokenized assets brought large corporate buyers of agricultural commodities to transact with the bank. Without such a platform, the banks had to incur significant costs in business development as well as in developing specific services to suit their needs.

6.1.2 Costs of accessing capital

The farmers and the SMEs had huge financial burden of not having access to capital and hence were easily exploited by unscrupulous intermediaries. Company A' solution allowed the farmers to get the much needed access to capital from the banks. Company B's solution provided cash in hand for agricultural SMEs quickly but it still depended on the quality check by the commodity exchange. This implied that the commodities had to be transported to the exchange, which incurred substantial costs. Company D tried to reduce transaction costs for farmers by bypassing the banking system and arranging funds from individual investors, who were paid a good interest rate but lower than existing commercial rates. Moreover, the produce could also be sold in the global market, achieving better prices.

6.1.3 Negotiation and contracting costs

Company C succeeded in reducing transaction costs for the commodity trading brokerage business. The current practice of telephone based contracting has risks associated with partners not honoring the contract within time as well increased time for contracting. The execution module of its platform increases certainty for trade execution which is a huge cost for trading houses. Thus, it reduces risks and the associated costs of negotiation and contracting. Company C also does not charge monthly brokerage fees, thus keeping the costs low.

6.2 Theoretical implications

Our analysis shows that the implementation of blockchain-enabled SCF solutions designed with the core objective of improving the financial conditions of farmers will differ from those with the core objective of reducing inefficiencies in the current process. For the first one, addressing the challenges on the ground and providing and communicating value from the solution to the users is very important. This should not only be marketed as a technology intervention but something which has the ability to improve their lives. Also, it is important to identify those users who will pay for the system and communicate the value to them. For the second type of solutions with the goal to reduce inefficiencies, the focus should be on identifying the root causes of the inefficiencies and address those in the solution while taking into account the user-friendliness of the system. Hence, we suggest the following propositions.

Proposition 1: Blockchain-enabled SCF solutions developed to improve the financial condition for farmers must consider the challenges faced on the ground and simultaneously provide value to the sellers (e.g., through reduced transaction costs and facilitated access to capital) as well as the customers (e.g., through reduced transaction costs and increased business).

Proposition 2: Blockchain-enabled SCF solutions developed primarily to reduce the inefficiencies of the current system must ensure that the platform is user-friendly and meet all the trade execution related requirements for the users.

6.3 Managerial implications

In this research we examine real blockchain-enabled SCF implementations in the agricultural commodity supply chain to outline the process of developing such solutions and the mechanisms by which those generate outcomes. Using TCE as the theoretical lens, t research identifies how blockchain-enabled SCF implementations reduce different types of transaction costs in the agricultural commodity supply chain. We also develop propositions for developing such solutions. Current literature on blockchain-enabled SCF implementation is limited and is either conceptual (Hofmann et al., 2018; Omran et al., 2017) or focusses on technological aspects using a single case study (Kim et al., 2020). Hence, we contribute to the body of knowledge on blockchain-enabled SCF implementation in supply chains, which currently lacks real implementation case studies and a sufficient theoretical underpinning. The findings of the study will benefit companies planning to develop blockchain-enabled SCF solutions as it will make them aware of the operational challenges and how they can overcome them. Specifically, we provide guidance on the design and implementation of such solutions. Blockchain implementation may be fraught with risks such as non-acceptance of the solution due to perceived complexity of its use. Such risks may appear because of digital divide and perceived apprehension about the technology as well as due to community effects. Agricultural stakeholders are usefully part of the same community or co-operatives and individuals may refrain from adopting technology due to fears of being different from others. Some of the mechanisms identified in this research can specifically address implementation risks: hands-on abilities and understanding local culture, emphasis on ease of use and value, recording trading requirements and blockchain-based electronic signatures and secure transactions. Moreover, if the cost of implementation are borne by financial intermediaries (e.g., banks) and customers of agricultural produce (e.g., food processing companies or food retailers) such risks can be avoided. Since the solutions developed were refined based on field trials and pilots, such risks are minimized. Service providers also actively consider outcome-based mechanisms such as developing user-friendly applications, providing technical support, and behavioral mechanisms such as involving locals and building relationships, educating customers and engaging with customers to minimize such implementation risks (Chaudhuri et al., 2021).

7. Conclusion, limitations and future research

In this paper we analyze four different blockchain-enabled SCF implementations in the agricultural commodity supply chain using CIMO analysis. Our analysis helps in understanding the context which led to the initial solution incubation and the refinement of those solutions to achieve the desired outcomes as well as the mechanisms by which those outcomes are obtained. Using the theoretical lens of TCE, we illustrate how blockchain-enabled SCF solutions reduce the different types of transaction costs such as search and information costs, costs of accessing capital and negotiation and contracting costs. We also develop propositions, which will guide development and implementation of the SCF solutions.

This research has certain limitations as it is based on four case studies. There are opportunities of future research to empirically validate the relationships between the interventions and the outcomes obtained from blockchain-enabled SCF implementations in agricultural commodity as well as other supply chains. There are also promising research opportunities to further develop cost-benefit models or Total Cost of Ownership models for such implementations as well as to identify risks associated with blockchain implementation in agricultural supply chains. Finally, risk mitigating mechanisms can be deployed to help create more efficient SCF solutions.

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Appendix

Interview protocol

1. Can you provide us with an overview of the challenges in your agricultural commodity supply chain?
2. What was the motivation to launch the blockchain solution? What challenges on the ground motivated the founder? Why did he believe that there was a need for such a solution?
3. How were the solutions developed?
4. Did the team conduct any pilot studies? Where and how did it work? What kind of challenges did you face during the pilot projects?
5. What kind of improvements were made to the solutions based on the pilots?
6. Have the solutions and offerings evolved over time? If yes, how?
7. Who are the beneficiaries and what are the benefits for them?
8. Can you explain the mechanisms provided by the solution which are helping in obtaining the outcomes for all the stakeholders?
9. What are the key success factors for implementing the solutions?
10. What kind of social and technical capabilities are needed to implement the solutions and for the users to adopt the solutions?

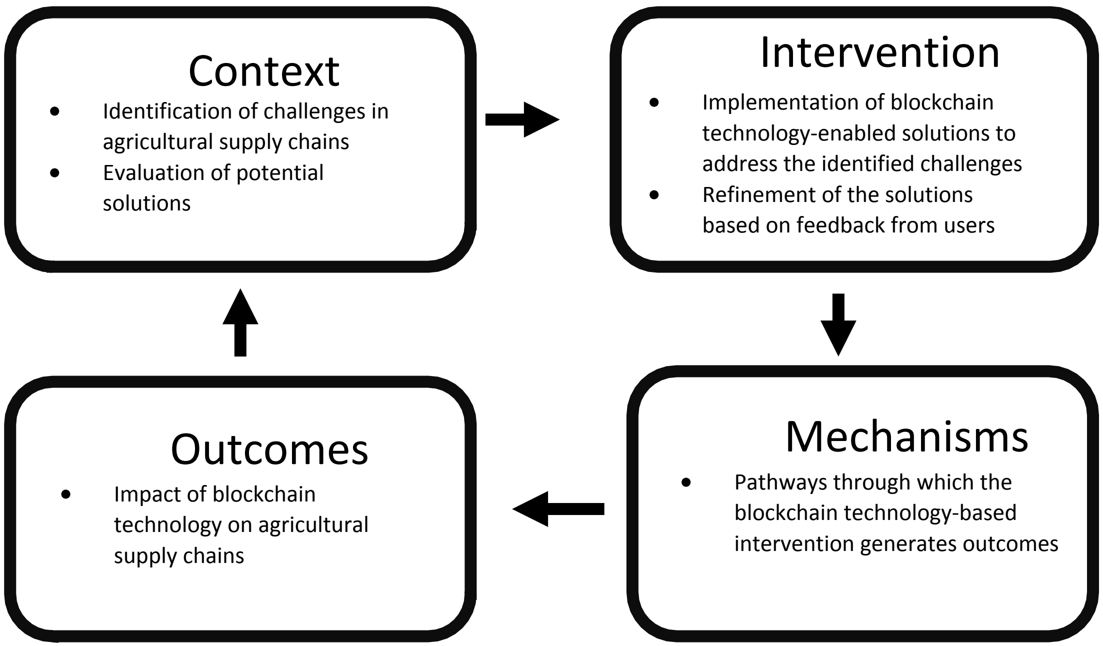
Context
Identification of challenges in agricultural supply chains
Evaluation of potential solutions
Intervention
Implementation of blockchain technology-enabled solutions to address the identified challenges
Refinement of the solutions based on feedback from users
Mechanisms
Pathways through which the blockchain technology-based intervention generates outcomes
Outcomes
Impact of blockchain technology on agricultural supply chains

Table 1. Validity and reliability criteria

Quality of research design	Case selection	Data collection	Data analysis
Construct validity		Triangulation of data using interviews, news articles, 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 which implemented SCF solutions in agricultural supply chains	Use of knowledgeable respondents, directly involved in the blockchain implementation projects.	Cross-case analysis
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 (Ellram 1996, Yin 2017)	Semi-structured interview guide included in case study protocol (Yin, 2017)	All interview transcripts analyzed by interviewers (Yin 2017)

Table 2. Overview of the conducted interviews and secondary data collected

Case company	Interviewee position	Duration of interview (minutes)	Secondary data collected
Company A	Co-founder	65, 48	3 documents on how the firm started, the motivation of the founders and its services 2 documents given by the founders to media A document on how the company is helping create sustainable food supply chains
Company B	Co-founder	54, 24	One interview, published in a trade magazine, with Company's founders, which outlined how Company was founded
Company C	Chief Operating Officer (COO)	32, 28	One news article, which outlined first trade of Black Sea wheat using Company's platform One document on how Company C, together with Grupo Ceres, Mexico created the world's first grain NFT (non-fungible token) on an export port terminal) One video from Company's website, where the COO outlines the unique characteristics of Company's platform
Company D	Communication and Business Development Manager	56, 32	Material from the website, which outlines company's business model and the impact created An internal document shared by Company D

Table 3. CIMO analysis of the cases

Cases	Context	Solution Incubation	Solution Refinement	Mechanisms	Outcome
Company A	• Liquidity problem for farmers • Lack of digitalization in the agricultural supply chain • Bank's limited business in the agricultural sector	• Attempt to become a digital broker	• Change of operating model by targeting banks as customers • Development of technological interface and embedding financial services capabilities into the platform • Minimum viable experimentation • Customizing to local requirements	• Ability to conduct performance assessment and risk assessment of farmers • Hands-on ability and understanding local culture • Emphasis on ease of use and value	• Change in balance of power • Upliftment of the local community • Efficient way of doing business and access to finance for agri SMEs • Increased deployment of financial services to the agricultural supply chain
Company B	• Liquidity problem for farmers • Exploitation of farmers by intermediaries • Bank's limited business in the agriculture sector • Manual lending process	• Tokenization of the warehouse receipts/commodities and execution of smart contract	• Offering a portfolio of solutions including inventory monitoring, supply chain financing, supply chain connect, which allows connecting with suppliers and buyers, receiving and agreeing offers, issuing	• Ability to bring all partners on the same platform • Secure transactions	• Efficient transaction and deal process • Increased business for banks

			invoices and get paid etc.		
Company C	• Grain trading business conducted over phone	• Executing commodity trade using smart contracts	• Improved filtering • Improved visualization • Including additional services	• Recording all trading requirements in one place • Blockchain-powered Advanced Electronic Signatures • Secure transactions	• Improved efficiency and less paperwork • Reduced uncertainty in deals • Less risk
Company D	• Liquidity issues for the farmers • High interest rates • Limited markets for the farmers	• Connecting lenders and farmers	• Not observed	• Ensuring returns to lenders while reducing financial burden for farmers • Secure transactions	• Change in balance of power • Efficient transaction and deal processes • Increased business for farmers • Upliftment of the local community