Centralization vs. Decentralization - supply chain networks and blockchain in the agri-food business

Centralização vs. Descentralização - redes de supply chain e blockchain no negócio agroalimentar

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ABSTRACT
Hierarchically organized businesses have been dominating our economy for centuries. We follow this structure for so long now because it is very efficient to allocating resources, performing coordination activities, and building relationships. However, potentially disruptive technologies such as Blockchain Technology (BCT), Artificial Intelligence (AI), and Internet of Things (IoT) have the potential to transform the centralized agri-food supply chain networks (SCN) into decentralized digital ecosystems, which will impact business processes and workflows alike. Still today the traditional agri-food SCN is characterized by a pyramid-hierarchic structure where decisions are being made by a central authority. It is typically headed by a focal firm which is responsible for the coordination of the network while determining the strategy and goals of the SCN. We investigated BCT use cases both in the agri-food industry and across several industries. Our literature- and use case-based research unveiled that supply chain use cases which have significantly higher operational implementations compared to their peers exhibit predominantly the following characteristics: they operate in a vertically coordinated ecosystem, they are dominated by a focal firm, and participation of suppliers is mandated by a central authority. The use cases displaying the mentioned characteristics have been found predominantly with consortium type of BCT platform implementations. As agri-food SCNs operate in vertically coordinated ecosystems we suggest that solutions such as provenance
or traceability in agri-food SCNs should be implemented based on consortium BCTs as those seem to support best the traditional agri-food SCN structure.

**Keywords:** vertical coordination, digital transformation, blockchain, supply chain, food industry.

**RESUMO**
Os negócios hierarquicamente organizados têm dominado a nossa economia durante séculos. Há tanto tempo que seguimos esta estrutura porque é muito eficiente na alocação de recursos, na realização de atividades de coordenação e na construção de relações. No entanto, tecnologias potencialmente disruptivas como a Blockchain Technology (BCT), Inteligência Artificial (IA) e Internet of Things (IoT) têm o potencial de transformar as redes centralizadas da cadeia de abastecimento agroalimentar (supply chain network = SCN) em ecossistemas digitais descentralizados, que terão impacto tanto nos processos empresariais como nos fluxos de trabalho. Ainda hoje o tradicional SCN agroalimentar é caracterizado por uma estrutura hierárquica em pirâmide, onde as decisões são tomadas por uma autoridade central. É normalmente dirigido por uma empresa principal que é responsável pela coordenação da rede enquanto determina a estratégia e os objetivos do SCN. Investigámos casos de utilização da BCT tanto na indústria agroalimentar como em várias indústrias. A nossa literatura e pesquisa baseada em casos de uso revelou que os casos de uso da cadeia de fornecimento que têm implementações operacionais significativamente mais elevadas em comparação com os seus pares apresentam predominantemente as seguintes características: operam num ecossistema verticalmente coordenado, são dominados por uma empresa principal, e a participação de fornecedores é mandatada por uma autoridade central. Os casos de uso com as características mencionadas foram encontrados predominantemente com implementações de plataformas BCT do tipo consórcio. Como os SCNs agroalimentares operam em ecossistemas verticalmente coordenados, sugerimos que soluções como a proveniência ou a rastreabilidade nos SCNs agroalimentares devem ser implementadas com base em BCTs de consórcio, uma vez que estas parecem suportar melhor a estrutura tradicional dos SCNs agroalimentares.

**Palavras-chave:** coordenação vertical, transformação digital, blockchain, cadeia de abastecimento, indústria alimentar.

**1 INTRODUCTION AND RESEARCH QUESTIONS**
Historically the organization of a firm has been characterized by hierarchies and centralization to efficiently allocating resources, performing coordination activities, and building relationships. Coordination and cooperation represent major attributes of inter-firm relationships and are of significant value
for the efficiency of the management of vertically cooperated food supply networks, which are typically managed centrally with a focal firm being responsible for the coordination of the network (Hanf and Dautzenberg, 2006a). The objective of the supply network is to maximize its value by improving the overall efficiency of the network by for example reducing the cost of transactions. Secure transactions, tracking and tracing including monitoring of transport and storage conditions relevant to food safety, as well as provenance information could lead to an increase of the value of the SCN. Driven by the digital transformation, vertically cooperated agri-food value chains have the potential to transform into decentralized, networked ecosystems. One of the key enablers in this process could be the BCT which forms the basis of the Bitcoin cryptocurrency ecosystem (Nakamoto, 2008). Its applications have already been adopted by several industries including but not limited to agriculture, finance, health care, manufacturing, and logistics. BCT with its decentralized architecture has the potential to significantly change the supply chain management (SCM) (Treiblmaier, 2018).

When referring to blockchain or BCT in this paper we use these as umbrella terms for the different BCT systems with their individual characteristics. Typically, the application of BCT in supply chain economics has been researched with an understanding of blockchain representing a single technology based on a single platform solution. We consider it as mandatory to distinguish between the three types of BCT platforms, which are public, private, and consortium because their differing attributes could have a profound effect on the efficiency of the agri-food SCN. We hypothesize that the choice of the BCT platform in strategic networks has an effect on coordination and cooperation of the network. Despite the increasing attention blockchain is getting, there is only limited scientific research about its economic effects on firms and on the efficiency of supply chains. The application of BCT in the agri-food supply chain has so far been predominantly researched from a technical point of view (Zhao et al., 2019a).
The aim of this paper is twofold. First, we want to contribute to the proper differentiation of the term blockchain and its platform typologies for the application in SCNs and second, we want to gain a better understanding of the economic impacts of the different platforms on coordination and cooperation of vertically cooperating agri-food supply chains through the comparison of their respective attributes.

RQ1: What are the implications of BCT platforms on the management of agri-food SCN?

RQ2: What are the key characteristics of the platforms causing these implications?

2 VERTICAL COORDINATION IN AGRI-FOOD SUPPLY CHAIN NETWORKS

Over the past few decades the agri-food business changed from vertical integrated to vertical cooperated networks. The redefinition and change of food quality – also driven by the food scares in the early 2000s – further stimulated the transfer towards vertical cooperation in SCNs coordinated by a focal firm (Hanf and Dautzenberg, 2006b). Hanf and Dautzenberg developed a managerial framework for supply networks in the agri-food business introducing the aspects of cooperation and coordination in combination with the three levels of management consisting of the firm, dyadic, and network level. Food networks have been classified as strategic networks (Hanf, 2005a) which are being characterized as pyramidal-hierarchical collaborations (Jarillo, 1988). Attributes of strategic networks are the hierarchical coordination through a focal firm, the intensity of relations, and the coordination mechanisms, which are all drivers of the chain management. Coordination can be understood as the alignment of actions to mutually achieve goals between intentionally chosen partners (Gulati, 2005). Coordination mechanisms in supply chains can be broadly divided into six groups: power, contractual relationships, information sharing, joint decision making, collective learning, and building routines (Belaya and Hanf, 2012; Handayati et. all, 2015). Pietrwicz examined consensus building and coding and
executing smart contracts as coordination mechanisms for online transactions (Pietrwicz, 2019a).

The focal firm acts as a “chain captain” (Hanf, 2005b) defining not only the target market for the SCN but also setting the joint strategy. It is also selecting the members that are becoming part of the network and manages the single relationships. Thus, the focal firm carries the overall responsibility for the network management. With this the focal firm is also taking responsibility for the food item and is standing in with its brand to ensure high product standards and product safety. The responsibility that a focal firm is taking by providing its brand and standing in for the quality and the safety of the food is a driver of vertical cooperation (Hanf, 2005c). Consumers are nowadays requiring detailed information about the food products in the supply chain which asks for agri-food firms to provide information such as provenance with the objective to increase trust which could increase customer loyalty. Hence, vertical cooperation in the agri-food industry are driven by trust and credence attributes such as food quality, provenance, and safety. Trust is a central driver for achieving cooperation in vertical cooperation (Rindfleisch, 2000) and trust and cooperation are also the most important organizational factors of the dairy food sector (Fink-Hafner et al., 2010). As trust in the agri-food supply chain is also being used to manage the risk of cooperation problems it is yet another driver of vertically cooperated supply chains (Hanf and Dautzenberg, 2006c).

3 DISTRIBUTED LEDGER TECHNOLOGY AND BLOCKCHAIN

Distributed Ledger Technology (DLT) is a shared ledger network of nodes connected peer-to-peer and distributed diversely across locations where the network is keeping ownership of all the records with identical copies of the ledger being distributed to and stored in all network nodes. Its key task is the validation of transactions in the network through joint consensus and also to determine the legal owner of a certain asset. DLT enables the real-time transfer of assets whereas the Internet enables only the transfer of information. It is a network of distributed nodes connected peer-to-peer and distributed diversely across
locations. The self-organizing peer-to-peer data-sharing technology operates without a central authority or intermediaries such as banks or brokers authorizing or coordinating transactions. DLT is an umbrella term that encompasses all BCT. It could act as a key enabler in the current transition from centralized to decentralized SCNs.

BCT is a distributed ledger system and a specific type of DLT enabling bi-lateral collaboration between participating entities. It utilizes hashing, a method to create immutable, encrypted, and time-stamped records of transaction data. In this shared ledger system records can only be updated if each party involved in a specific transaction authorizes the updates. The chained data blocks are managed by distributed individual networked entities that are not owned by an intermediary or central entity thus eliminating the need for any intermediaries. In contrast to BCT distributed ledgers do not require such a chain and by their nature they also do not require proof of work (PoW) as consensus mechanism. It can be viewed as a meta-technology as it comprises of various existing technologies that are, intelligently combined, creating a new technology (Kamble, 2018). DLT and BCT are oftentimes used as being interchangeable. A clear distinction between the two terms as well as a clear definition of BCT and its capabilities is vital to further analyze the impact of BCT on coordination processes in the supply chain. Various and mostly overlapping definitions of the BCT exist today, most of them having their roots in the technology space. Obviously, due to the nascent state of this technology there has not yet been agreed upon a general definition of BCT. We therefor use the following definition in this research that encompasses economical as well as technical aspects:

*Blockchain is a software protocol that governs the rules for securely transferring assets incorruptibly over the Internet. It enables peer-to-peer collaboration in decentralized networks eliminating the need for third-party intermediaries or a centrally coordinating trust entity. Transactions are verified by the participating entities and the contents of its shared ledger is constantly synchronized across all nodes of the network. Immutability of data, security through cryptography, mass consensus, and transparency of transactions acts as its trust attributes.*
BCT also enables software-coded smart contracts that autonomously perform transactions accelerating and automating business processes. Smart contracts are software programs that are based on BCT with fixed rules for automatically executed transactions based on a set of predefined conditions that have to be met (Kõlvart et al., 2016). Tasks such as the payment of a good when the good arrives according to the agreed upon contractual conditions are being executed autonomously without a monitoring authority. Key benefits of smart contracts are the increased transparency and trust in a decentralized system with no single ruling authority (Zhao et al., 2019b) and the reduction of ex-ante and ex-post transaction costs (Ciatto et al., 2020). Smart contracts in BCT can be seen as coordination mechanisms applying an institutional perspective over coordination (Frantz and Nowostawski, 2016). A token, the digital, alphanumerical representation of a physical asset, are the simplest form of a smart contract.

BCT with its trust attributes immutability of data, cryptographic security, mass consensus, and transparency could create a new trust platform for business transactions as the application of disruptive technologies such as BCT to the agri-food supply chain management can increase trust by generating closer relationships between the firms (Aste et al., 2017).

4 BLOCKCHAIN - AN INSTITUTIONAL TECHNOLOGY

Some scientific literature categorizes BCT as a disruptive technology (Furlonger and Unzureau, 2019), others as institutional technology (Davidson et al., 2018a) or it is being declared as foundational or general-purpose technology (Pietrewicz, 2019; Kamilaris et al., 2019). In addition, there is a shift in positioning BCT as a foundational rather than a disruptive technology as one of the most important digital trends (Panetta, 2018). However, even research on BCT as a foundational technology addressing economic and business aspects is scarce (Risius and Spohrer, 2017). There is also the discourse positing it as an institutional technology (Davidson et al., 2018b). In their research Davidson et al. conclude that DLT can be approached by two economic theories: through
Schumpeter’s Neo-Classic Economics or through Williamson’s New Institutional Economics. Following Schumpeter, BCT could be looked at as a new technology which increases productivity, inducing a destructive effect on firms, economy, and society. Schumpeter examines disruptive technologies as a technology which increases total factor productivity in existing economic operations which has “creative destruction” effects on firms and markets. BCT is revolutionizing governance and are competing with the traditional economy and following Williamson’s NIE theory, BCT and DLT are being viewed as institutional technology (Akansel, 2016). Davidson et al. elevate BCT beyond just being a disruptive technology but rather as being “a new institutional technology of governance that competes with other economic institutions of capitalism, namely firms, markets, networks, and even governments” (Davidson et al., 2018c). As the change in governance is key to our research, we will follow the institutional view of Davidson et al. and view BCT as an institutional technology utilizing aspects of the transaction cost theory.

5 BLOCKCHAIN PLATFORMS

Three different BCT platforms exist today: the public, private and consortium BCT platform. They are differentiating through access rights and rights to read and write in the ledger. What all BCT platforms have in common is the distributed ledger technology, peer-to-peer transactions, as well as a consensus mechanism. In the public blockchain consensus is achieved through the majority of the participating entities utilizing the Proof of Work (PoW) algorithm. The public BCT network is open for participation to everyone and everyone can access the transaction data, validate it, and participate in the consensus process. This type of BCT platform is called permissionless as no permission from an authority is needed to participate in the network. Transaction data, once validated, is secure and immutable. In a private BCT platform only approved and authorized members can participate in the network. A single ruling authority is coordinating the permissioned access and validation of transactions. Private BCT platforms are mainly used in enterprise environments. As the
decisions are being made by a central authority network consensus remains in one hand and is as a consequence much faster compared to those in public BCT platforms. As a result, transaction throughput can be much higher. A consortium BCT is also a permissioned technology as only authorized participants will be granted access to the network. In contrast to the private platform the network is being controlled by a group of entities, such as several firms, having equal rights and maintaining the network and system technology. The system is decentralized, permissioned and only authorized users will be granted access. Its aim is rather collaboration than competition between the participating firms. Cost savings, accelerated learning, and sharing risks are the top benefits organizations expect from a certain consortium according to a recent research conducted by Deloitte (Pawczuk et al., 2019).

6 DISTINCTIVE REQUIREMENTS OF AGRI-FOOD SUPPLY CHAINS

The current agri-food supply chain systems are lacking transparency and are highly inefficient. It is estimated that two thirds of the final cost of the agricultural goods are needed to operate the supply chain (Tripoli and Schmidhuber, 2018). Processes in the supply chain are also being impacted by the multitude of intermediaries. Traceability is becoming an increasingly urgent requirement and a fundamental differentiator in many supply chain industries including the agri-food sector (Costa et al., 2013). The distinct requirements of agri-food supply chains are transparency of the food products in the supply chain to enable tracking and tracing and rapid product recalls, which are enterprise driven requirements. Consumers are expecting provenance information about the origin of the products, which will in return increase the trust with the brand. The requirement for supply chain transparency can be met by implementing BCT and DLT based solutions (Blossey et al., 2019). In order to assess BCT opportunities Carson and Higginson performed an analysis of the use-cases for several industries including agriculture. The impact of BCT proved to be very high in the agricultural supply chain while food safety and origin even surpassing the high impact level (Carson and Higginson, 2018). Gartner unveiled in a survey
conducted in 2019 that the most successful use cases are those that address an urgent business need (Groombridge, 2020). They also showed that provenance and traceability are amongst the fastest growing use cases for BCT.

7 MATERIALS AND METHODS

We based our research on extensive literature review both concerning vertically coordinated agri-food supply chain as well as review of BCT in agri-food SCNs. Two case studies in the German agri-food industry were identified and formulated. Two further case studies were identified within the US American agri-food sector.

8 RESULTS AND DISCUSSIONS

Our paper focused on the proper differentiation of the various BCT platform typologies and how the different platforms impact the management of vertically cooperating agri-food SCNs. Strategic networks in the agri-food business need a focal firm because this central authority is responsible for the strict vertical coordination of the food supply chain and ensures that credence attributes such as product quality, information about provenance, transparency of activities in the supply chain, etc. will be transferred to the consumer reliably and uncompromisingly.

Our research shows that the choice of the BCT platform has an impact on coordination and cooperation in agri-food SCN. We identified six coordination mechanisms in the agri-food supply chain and applied those to the three BCT platforms. The comparison shows that each platform addresses the way how power is being exerted, the way how information is shared, joint decision making, and collective learning differently. Solely the mechanisms of how contractual relationships are being managed and how building routines is being addressed can be viewed as being similar for all platforms. Use cases based on private BCT solutions, which are being managed by single enterprises are a centralized solution with a single authority exerting power on the participants, controlling the transaction data, and making decisions in the supply chain. Such a private BCT
provides a similar solution as a cloud platform. A key difference is that data that is being written to the BCT ledger remains immutable. Provenance based as well as tracking and tracing use cases have been identified with the cases we investigated. The first one is a coffee producer, which provides consumers with access to provenance information. The business challenge was to provide trusted information about the coffee products in the supply chain in their quest to further increase customer loyalty as consumers are increasingly asking producers to make the supply chain processes more transparent to them. The other agri-food use case investigated is operated by a producer of frozen food products including fish, and vegetables. Their business requirement is to further increase trust in their frozen fish products and as a result increase customer loyalty by providing reliable provenance data about the place where the fish was captured. The BCT based solution provides provenance data and enables consumers to verify provenance information. Both use cases are based on private BCT solutions which could be transformed into consortium BCTs when they are opened to include external firms. Power in consortium BCTs is being held by a few firms rather than by a single one as in private ones. The information in the supply chain is being shared between all participating entities and decisions are being made jointly. At the same time all participants benefit from the experience of other network members and through joint learning. We found that BCT use cases that have successfully reached the operational stage follow a certain pattern. First, and foremost the use cases operate in a vertical ecosystem similar to the traditional vertically coordinated agri-food supply chain represents. Second, a focal firm takes responsibility for the management of the SCN. And third, participation in the BCT enabled SCN is required by the focal firm from its suppliers. The progress is fastest in those cases where adoption is pushed on the participants by the focal firm. Walmart for example obliges in its Food Traceability Initiative, which is based on IBM’s Food Trust network, its suppliers of fresh leafy greens to participate in their BCT to enable transparency and provenance in their quest to increase food safety by radically reducing the time to recall products. Another consortium-based use case is the Food Trust solution.
IBM started Food Trust back in 2017 and connects participating firms in the food supply chain to share food system data of their products. The driving force to develop Food Trust was to provide a platform that would be able to rapidly activate food recalls if needed and to keep the lot of recalled products as small as possible in order to eliminate unneeded and excessive waste. In contrast to private BCT use cases these consortium-based ones integrate different firms in the food supply chain ecosystem.

9 CONCLUSIONS

The choice of the BCT platform will have a profound effect on the efficiency of the agri-food SCN because coordination mechanisms are being addressed differently by the various platform types. The use cases we researched have in common that they operate in permissioned systems that are centrally coordinated. With BCT induced solutions participating members of the SCN should perform transactions peer-to-peer with each other without any central authority coordinating the SCN. We identified the use cases that have shown a higher proportion of operationalization compared to other use cases. We conclude that successful implementations need a vertically coordinated ecosystem and revolve around providing provenance as well as tracking and tracing information, both needed as credence attributes in the agri-food industry. We found that the current BCT use cases are predominantly successful when the participation of firms is mandated by a centrally acting entity. With the introduction of tokenization smart contracts could not only further increase the transparency in the supply chain but also enable autonomous transactions based on electronic contracts which has the potential to reduce ex-ante and ex-post transaction costs. However, the current solutions do not include tokenization of assets. Further research has to show how the introduction of smart contracts impact the remaining two coordination mechanisms in supply chains which are contractual relationships and building routines.
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