EXPLORING THE IMPACT OF DECENTRALIZED AUTONOMOUS SUPPLY CHAINS (DASCs) IN THE AGRICULTURAL SECTOR: AN INNOVATION ASSIMILATION PERSPECTIVE

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Abstract

Blockchain, distributed ledger technology (DLT) and smart-contract technology enhance the effectiveness and automation of business processes along supply chains. The rising interest in the development of decentralized autonomous organizations (DAO) shows that blockchain and related decentralized technologies have the potential to reform how businesses conduct their supply chain operations. A DAO is an organization wherein business rules are encoded in smart-contract programs that are executed automatically when specified rules are met. There is a scarcity of research that has examined the impact of blockchain technologies in facilitating decentralized autonomous supply chains in the agricultural sector. Therefore, the purpose of this paper is twofold. First, we introduce a new concept to the blockchain literature called decentralized autonomous supply chains (DASCs) and discuss how this new concept can overcome the challenges associated with extant centralized agricultural supply chains. Finally, we also propose a framework that can explore how the concept of DASCs assimilates into agricultural supply chains to assist organizations with the realization of benefits not originally conceived with blockchain technologies.

1. CENTRALIZED AGRICULTURAL SUPPLY CHAINS

An agriculture supply chain can be defined as "a set of actors involved in farming, distribution, processing, and marketing of agricultural and horticultural products, from field to table" [1, p113]. Agricultural supply chains play a vital role in Europe's economy in terms of not only constituting a key supply source for its citizens' consumption requirements but also from a financial perspective and economic growth perspectives. According to EuroStat, "the European Union's (EU) agricultural industry created an estimated gross value added of EUR 178.4 billion in 2020 and added 1.3 % to the EU's GDP" [2]. Currently, EU agricultural production revolves around grain, livestock (beef and dairy), vegetables, wine, and sugar. The traditional information technology and information systems enabling agricultural supply chains are largely centralized. There is also a digital divide which makes the capturing of real-time information throughout agricultural supply chains challenging [3]. This can lead to a number of challenges in terms of trust, product traceability and tracking, quality assurance control, auditing, forensics, market price transparency, impaired data and information sharing, high transaction costs, and food fraud. These challenges were compounded and made increasingly evident during the COVID-19 pandemic which resulted in food shortages, declining outputs, labour disruption, and most significantly severe supply chain disruptions.

There is also a need for enhanced traceability from farm to fork in agricultural supply chains. The addition of pesticides in vegetables and hormones to food products to enhance their life cycles can lead to residual elements ending up in the final product which has negative health consequences for consumers. Furthermore, the European Green Deal (EGD) and the EU's "Farm to Fork Strategy" aims to reduce agricultural supply chain's carbon footprint and carbon emissions by 2030 by making them more sustainable, robust, and resilient. Consequently, there have been calls for agricultural supply chains to become more resilient using innovative agricultural technologies (agri-tech) such as blockchain, distributed ledger technologies, and artificial intelligence [4, 5]. Additionally, Horizon Europe, the EU's key funding programme for research and innovation, aims to fund projects that are underpinned by digital technologies and nature-based solutions for making agricultural supply chain processes more sustainable.

2. DECENTRALIZED AUTONOMOUS ORGANIZATIONS (DAOS)

Decentralized autonomous organizations (DAOs) can be defined as organizations where the interaction of its internal and external stakeholders is mediated by a set of business logic which is coded onto a blockchain smart contract and subsequently executed when specific terms and conditions are met [6]. Thus, DAOs can be described as a novel manner of self-coordination which is made possible by blockchain technologies. There are several characteristics which differentiate traditional centralized organizations from DAOs. First, blockchain decentralization enables DAOs to realise new supply chain business models which are underpinned by the concept of disintermediation. For example, decentralized finance (DeFi) where customers can avail of cryptocurrency liquidity (borrowing and lending) sans third party banking institutions and traditional know-your-customer (KYC) requirements). *Compound.Finance* [7] is an example of a DAO DeFi company which enables borrowers to avail of cryptocurrency loans once they satisfy overcollateralized loan requirements. For instance, borrowers must have an initial amount of cryptocurrency allocated to a liquidity pool which enables them to avail of a 70% equivalent of this allocated amount for a loan. Second, the organizational governance of DAOs is substantially different from traditional organizations whose top-down driven decision making is a hallmark of centralized operating organizations. In DAOs, governance procedures are controlled by protocols which are specific to the blockchain technology being used by the organization. This method encompasses peer-to-peer (P2P) collaboration and innovation in a trustless ecosystem [8]. Finally, the permission access privileges inherent to blockchain technologies enable organizations to leverage the benefits of permissioned (private) and permissionless (public) blockchain technologies. For example, DAOs that operate permissioned blockchains can unlock distinctive supply chain value propositions which can be deployed in commercial confidence, with small-scale proof of concept projects being scaled up over time. Having presented these innovative and nuanced characteristics, we will now introduce the concept decentralized autonomous supply chains (DASCs) in the next section.

3. DECENTRALIZED AUTONOMOUS SUPPLY CHAINS (DASCS)

Having already discussed the challenges of centralized agricultural supply chains, and the Emergence of DAOs**,** this section will introduce a new concept called DASCs as a digital innovation which has the potential to overcome these challenges. An autonomous supply chain possesses the capacity to carry out supply chain activities and business processes without human intervention. The core benefits of an autonomous supply chain include, intelligence, standardization, interconnectedness, enhanced agility, improved customer services, and reduced fees and costs [9]. A recent survey of supply chain leaders [10] noted how 90% of those surveyed identified that "implementing an autonomous supply chain can lead to improved supply chain resilience and flexibility, smoother fulfillment, and optimized inventory and logistics". Current technologies enabling the automation of physical and digital aspects of supply chains include 5G connectivity, robotics, drones, the Internet of things, machine learning and artificial intelligence [11]. While there are a multitude of benefits associated with autonomous supply chains there are a number of challenges which could potentially hinder its adoption by organizations. The first challenge relates to poor supply chain data information flow, particularly regarding demand information, supplier information, and logistics information. This is compounded by poor data availability and data quality and the failure along some parts of a supply chain to capture data points which results in "data/information blind spots". The second challenge relates to the costs and time involved in disputes which arise from traditional contracts amongst stakeholders in a supply chain. The more complex a contract is the more it requires control and the greater the risk of disputes emerging. We argue that one way to overcome these challenges is to decentralize autonomous supply chains using blockchain and smart contract technology, which would result in DASCs. DASCs would enhance information and data flow along supply chains providing end-to-end visibility for all supply chain stakeholders and enabling an immutable and single source of truth. In terms of agricultural supply chains, this would lead to enhanced demand forecasting accuracy in real-time. This would also enhance market transparency. A lack of market transparent in the agriculture supply chains can lead to "information asymmetries and inefficient markets and give those with access to the most accurate data disproportionate power" [12]. Next, DASCs underpinned by smart contract technology can overcome the challenges associated with traditional contracts. Smart contracts are translations of an agreement, including the terms and conditions into a computational code. An example of a smart contracting coding language is solidity which can be used by programmers to codify business logic contained within a traditional contract into a set of rules that are automatically validated and executed on the blockchain. For instance, "If X provides a service, Y pays for it". Ultimately, smart contracts do not need human intervention to validate and execute the terms and condition of a contract. Additionally, these smart contracts are secured by cryptography. Figure 1 highlights how a DASC could operate. In this scenario, an agricultural vaccine product is shipped by a pharmaceutical manufacturer (Party A) with an intended destination to a veterinarian (Party B). The vaccine is shipped with an IoT sensor which monitors the temperature of the vaccine. This temperature data is broadcast to all supply chain stakeholders by the logistics company (Party C). Should the temperature increase above a certain threshold which renders the vaccine useless the product's serial number is flagged and withdrawn from the supply chain. This intervention is carried out via a smart contract where the above set of rules has been coded onto the blockchain. An example of how this would work is discussed in [13]. We propose that this new DASCs could dramatically improve agricultural supply chain operations. In the next section, we propose a framework that can analyse the impact of DASCs in an agricultural supply chain setting.

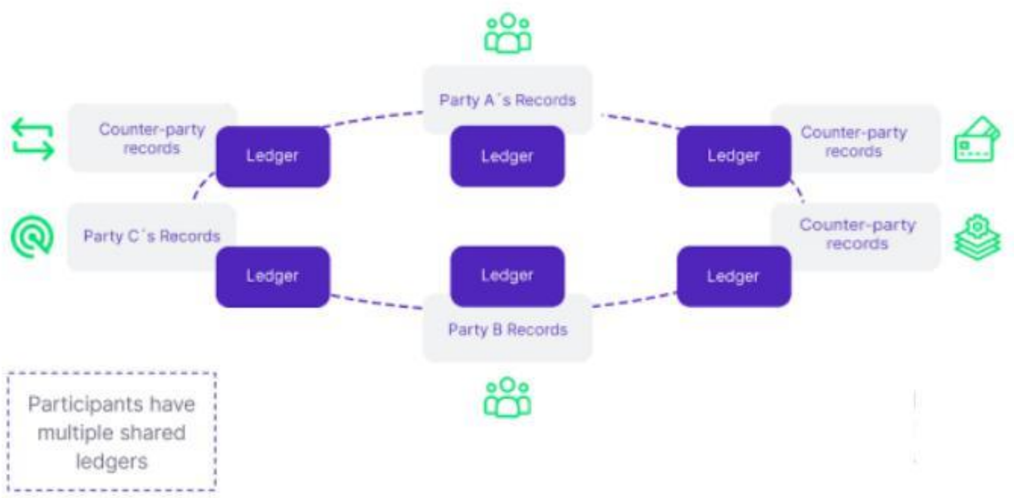

Figure 1: A Decentralized Autonomous Supply Chain

4. INNOVATION ASSIMILATION

Assimilation can be defined as an organizational process that "(i) is set in motion when individual organization members first hear of an innovation's development, (ii) can lead to the acquisition of the innovation, and (iii) sometimes comes to fruition in the innovation's full acceptance, utilization, and institutionalization" [14, p. 897]. The assimilation of technological innovation can often be challenging and is rarely binary [15]. Innovation assimilation theory posits that assimilation may intensify or deteriorate throughout a technological innovation's adoption journey [16]. Each assimilation stage describes the degree to which the technological innovation permeates the adopting company. Often the causes of innovation success or failure can be minute. While many frameworks have been proposed to understand how innovation assimilation impacts entities, one of the most widely cited and used is proposed by Gallivan [15]. Table 1 provides an overview of this six-stage model. The framework comprises two preadoption 'early stages' (e.g., initiation and adoption) and 4 post-adoption 'later stages' (e.g., adaptation, acceptance, routinization, and infusion). The infusion stage comprises several different facets of technology innovation infusion: *extended use*, *integrated use*, and *emergent use*. However, based on the findings of a recent study, (Clohessy, 2022) we identified two additional phases that were present in the infusion stage with regards to blockchain technology: *diffused use* and *entrenched use*. By *diffused use*, we mean that as an adopting organization's supply chain customer base expands so do the external channels through which the technology is used. For example, as an adopting organization's customer size increases so too do the customer's requirements for additional features for the adopting organization's blockchain products and services. Generally, diffused use can only be achieved once the adopting organization has achieved a significant amount of experience with the technology internally prior to rolling out bespoke features to external partners. By *entrenched use,* we mean that the adopting organization starts to create their bespoke blockchain products and services which are hard to imitate by rivals. Additionally, this stage is characterized by the fact that the technology is deeply rooted in all the core functionalities of the organization and is essential to the day-to-day running of supply chain operations.

TABLE 1. The Innovation Assimilation Stages of Blockchain Supply Chain Adoption

Assimilation stages	**Supply chain blockchain adoption**
Initiation	A match is found for a technological innovation and its application in an organization.
Adoption	A decision is reached to invest resources to adopt the technological innovation.
Adaptation	The technological innovation is developed, installed, and maintained. Organizational members are trained to use the new technological innovation.
Acceptance	Organizational members are induced to use the technological innovation which is now being used within the company.
Routinization	The use of the technological innovation is encouraged as a normal activity and organizational structures are altered to accommodate the technological innovation. It is no longer seen as something out of the ordinary.
Infusion	The technological innovation is used in an elaborate and sophisticated manner. Infusion is categorized in several ways: • **Extended use:** using more features of the technological innovation. • **Integrative use:** using the technological innovation to create new workflow linkages among tasks. • **Emergent use:** using the technological innovation to perform tasks not previously considered possible. • **Diffused use:** implementing additional features to cater to individual customer bespoke blockchain technology requirements. • **Entrenched use:** using the technological innovation to create patented blockchain services and products.

5. CONCLUSION

This paper presented several core contributions. The first is that it introduces the concept of decentralized autonomous supply chains (DASCs) and to the best of our knowledge this concept has not been referred to in previous literature. We then applied the concept to the agricultural industry as a catalyst for overcoming the challenges associated with extant agricultural supply chains. Finally, we proposed a framework for exploring how DASCs could potentially impact the supply chains of agricultural organizations contemplating adopting blockchain and DLT.

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