DIGITALIZATION OF AGRI-FOOD SUPPLY CHAINS: FACTS AND PROMISES OF BLOCKCHAIN TECHNOLOGY

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Abstract With the globalization agri-food supply chains become longer and more complex, what makes it difficult to manage. parallel with this there is increasing customer demand for knowing the origin, ingredients and delivery chain of agricultural products. the need for more efficient, traceable and visible supply chain for agri-food products appears from supply side. The digital methods of industry 4.0 are able to provide solutions for these demands particularly those which are able to trace product reliable way from its origin to consumption. blockchain is a disruptive technology by which every important product information can be collected, stored and shared with the actors involved in the product process chain from the first phase to the final customer. The paper provides an overview about blockchain technology and its operation in agri-food supply chains environment, then presents some examples from the practice of different countries where blockchain was applied in the agricultural sector in order to introduce experiences as facts, and further possibilities as promises by blockchain.

Keywords: digitalization, agrifood, supply chain, blockchain, technology

University of Maribor Press

DOI https://doi.org/10.18690/978-961-286-538-2.3
ISBN 978-961-286-538-2

1 Introduction

In 2030, the world's human population is predicted to touch 8.6 billion (Farmingfirst & CGIAR). One of the impacts of this phenomenon is that natural resources are decreasing and their availability must be safeguarded and workers working in the agricultural value chain are at stake as well. The challenge is to make our food systems more sustainable which is depend on innovative tools and approaches being developed and deployed around the world. Sustainable food systems are interconnected and represent the full agri-value chain, from pre-production and production to supply chains and consumption. In addition, the amount of data in our world is increasing rapidly (Zyskind et al., 2015). Across the industries, leading companies are trying to implement their own proprietary authentication software where they function as a centralized trusted authority.

Supply chain (SC) refers to the design, engineering, production and distribution processes of goods and services from suppliers to customers (Muckstadt et al., 2001). The agriculture supply chain (ASC) is like any consumer product supply chain that includes the suppliers, leading firms, customers, and distribution partners. The primary difference is that either animals or humans consume the final products, and the raw material is grown in farms using agricultural practices (Miranda-Ackerman & Azzaro-Pantel, 2017).

Nowadays, agriculture supply chain is very complicated by fragmented inbound and outbound networks (Denis et al., 2020). The complexity can come from across industries, with multiple functions interacting with different, potentially conflicting objectives and numerous dependencies between material and information flows. In recent years both consumers and the participants of agricultural and alimentary sectors presented more and more interest regarding product information in order to maintain customer’s trust and supply chain reliability. The increasing trend of origin oriented consumption in the developed countries is further stimulating the need for a solution is able to support of information availability during the life of product in supply chain. Customers are interested in what happens during the steps of supply chain process. The deficiencies of traceability, lack of information for the consumer about the origin, process and shipment of products, needs for transparency and visibility, problems of data management i.e. collection and sharing of product information, problems of centralized supply chain management are also such reasons drive to find a supply chain wide method (Azzi et al., 2019).

The main challenge of the supply chain remains in the traceability and data management system (Azzi et al., 2019). In addition, a centralized management system could represent a threat to data integrity, availability, and resiliency, leaving the system subject to corruption fraud and tampering (Abeyratne & Monfared, 2016). Advances in digital and analytics technologies offer a way to optimize the agriculture supply chain. The agriculture industry is capturing more data than ever, on everything from agronomy to the weather to logistics to market price volatility. Data storage capacity has increased, storage cost has plummeted, and computational power has grown (Denis et al., 2020). Agriculture digitalization can be a solution for these problems. Implementation blockchain technology as agriculture digitalization is one of the disruptive technologies of industry 4.0.

A blockchain is essentially a distributed database of records, or public ledger of all transactions or digital events that have been executed and shared among participating parties. Each transaction in the public ledger is verified by consensus of a majority of the participants in the system (Rosby et al., 2016). Blockchain can work in a decentralized environment, which is enabled by integrating several core technologies such as cryptographic hash, digital signature (based on asymmetric cryptography) and distributed consensus mechanism The blockchain technology has the key characteristics, such as decentralization, persistency, anonymity and auditability (Zheng et al.2018). Fraud and malfunctions can thus be detected quickly. Moreover, problems can be reported in real-time by incorporating smart contracts (Haveson et al., 2017; Sylvester, 2019). Smart contracts are basically computer programs that can automatically execute the terms of a contract (Rosby et al., 2016). Considering the above arguments, the main objective of this paper is to observe facts, problems and promises of blockchain technology in agri-food sector. Regarding above arguments, this paper presents an overview and collects the benefits of blockchain in agri-food supply chain, then shares practical experiences from different countries tried blockchain in various branches of agricultural sector. The paper is organized as follows: section 1 contains introduction; section 2 provides an overview of blockchain; section 3 describes the research method; section 4 presents experiences concerning blockchain application and section 5 concludes the achievable benefits of blockchain.

2 Overview of blockchain

The blockchain technology is based on the distributed ledger. A distributed ledger is a database that is updated independently by each participant (or node) on a large network (Presthus & Omalley, 2017). Blockchain is a distributed ledger that is shared and agreed upon a peer-to-peer network (Crosby et al., 2016) (Sternberg & Baruffaldi, 2018). A blockchain contains a single record of the data which is stored in blocks on every participant's node (Yli-Huumo et al., 2016). Each block corresponds to a timestamped record that is verified through a defined consensus protocol of the blockchain network and secured via public-key cryptography ('hashing') (Seebacher & Schuritz, 2017).

There are two main characteristics of blockchain technology that are important for its implementation and meaningful use in logistics and supply chains/supply networks (Kawa & Maryniak, 2019):

- Secure, verified, trustable exchange of information through blockchain in real time that makes them accessible to all members of supply network or to anyone else (depending on the type of blockchain),
- Possibility of automatic verification and execution of agreed transactions when certain requirements are met through smart-contracts-applications that are living on blockchain (Christidis & Devetsikiotis, 2016).

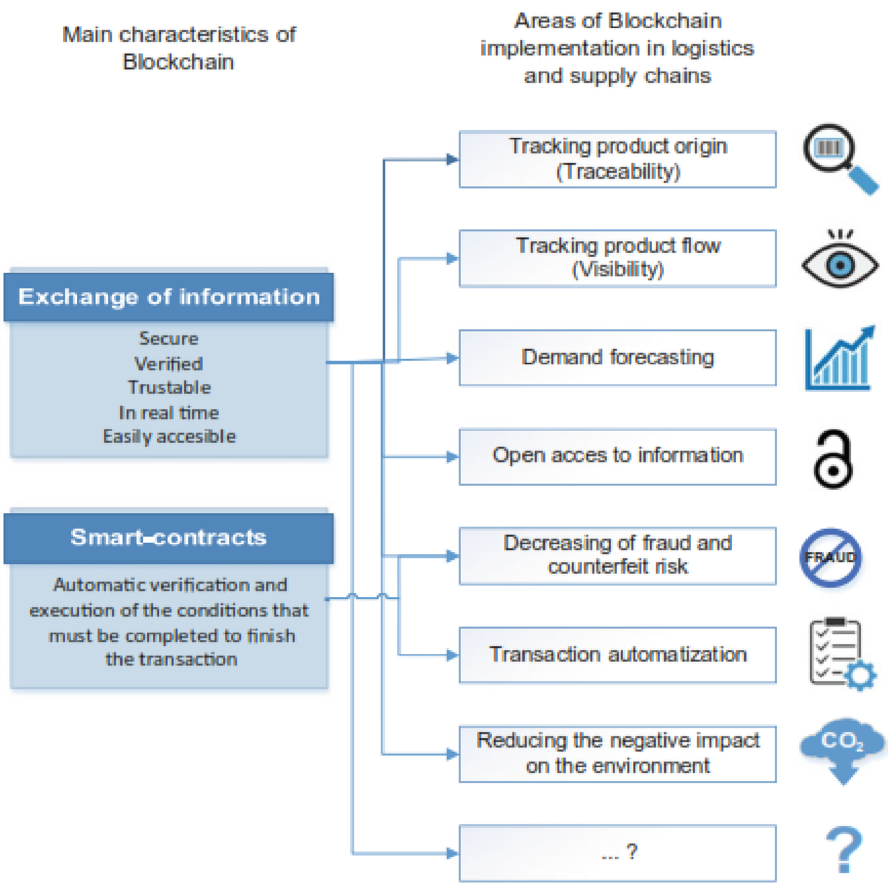

Figure 1: Characteristics and implementation areas of blockchain in logistics and supply chain.

(Source: Kawa & Maryniak,2019)

Based on these main features of blockchain, implementation areas for its use in logistics and supply chain are being developing in various directions. Some of the most important current implementation areas of blockchain in logistics and supply chain are tracking product origin as well as tracking product flow through supply network, demand forecasting, decreasing of counterfeit and fraud risk, open access to information in supply chain, reducing the negative impact on the environment and transaction automatization through smart contracts. In many cases, implementation areas of blockchain are combined in supply chain management, and blockchain is simultaneously used for example for tracking product origin and flow, but also for decreasing fraud risk and more accurate demand forecasting.

2.1 Agricultural Supply Chain

Agricultural supply chain is a complex system which responsible for the circulation of agricultural products in the market. As the carrier of the circulation of agricultural products, agricultural commercial resources are important guarantee to meet the demand of agricultural products and to maintain their quality and safety (Leng et al., 2018). It is critical to ensure these value chains running smoothly and successfully by applying advanced internet technologies. Supply chain management deals with production, refining, delivery, selling consumption, and disposal (Kamble et al., 2020). The process of the supply chain is summarized in Figure 2. In developing countries, the food supply chain faces several challenges, such as the need for confidence among stakeholders which often correlated with their credibility and traceability required by the end-users, and the difficulty of managing risks, delays, or disruptions is often occurred due to insufficient or lacking information (Kittipanya-Ngam & Tan, 2020). Blockchain technology is one of the best ways to meet these challenges (Niu & Li, 2020)

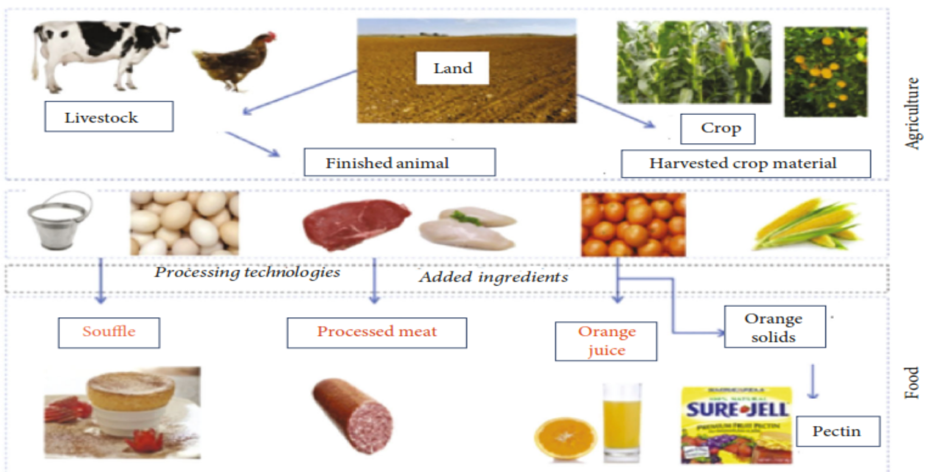

Figure 2: Agricultural food supply chain process.
(Source: Sabir et al., 2021)

3 Research Method

Providing an overview regarding the nature, operation and application of blockchain in the supply chains a secondary research was conducted. In order to know and apply the past experiences of different pilot projects in some countries some examples were collected from various sectors and supply chains also from food supply networks. By the pilots the quantifiable positive impacts can be gathered as well as the conditions needed for the application, furthermore difficulties could be appeared during the implementation and application process. By several examples general impacts can be classified related to sectors or supply chains and best practices can be identified for particular fields. This paper provides information in agri-food supply chains' perspective from various scientific and practical sources such as comparative analyzes, literature reviews, research findings, use cases, case studies or white papers (citations).

4 Experiences of blockchain application

Feng Tian (2016) proposed a new decentralized traceability system based on RFID and blockchain in China. The current centralized logistic system creates the agri-food loss ratio is between 25 % and 30 % in China annually. New, decentralized traceability system could increase the transparency of the supply chain, strengthen the information credibility, realize the real-time tracking of agri-food, and consequently, enhance the safety assurance of the agri-food supply chain.

Stranieri et al. (2021) researched the impact of implementation blockchain technology which are transparency and traceability the information flow of poultry, lemon, and oranges supply chain in a large European retailer and found that blockchain has a positive effect on the profit or return on investment of the agri-food supply chain. It improves the quality of products by improving consumer satisfaction by giving an access to information and the possibility of feedback, as well as by creating transparency and sharing information between stakeholders. Table 1 showed the measurement of impacts received by interviewing between Stranieri et al. and retailers.

Themes/Measures	Poultry supply chain		Lemons supply chain		Oranges supply chain	
	Producer	Retailer	Producer	Retailer	Producer	Retailer
Themes/Measures* from *the conceptual framework						
Efficiency						
Production/Distribution costs	0	0	0	0	0	0
Profit	+	+		+	+	+
ROI (Return on investment)		+	+	+		+
Flexibility						
Customer satisfaction	0	+	+	+	0	+
Volume	0	0	0	0	0	0
Delivery	0	0		0	0	+
Number of lost sales					0	
Responsiveness						
Fill rate	0		0			
Lead time	0	0		0		0
Product lateness		0		0	0	0
Customer complaints			+			
Shipping errors					0	
Food quality						
Intrinsic quality attributes/product characteristics	0	++	0	++	+	++
Intrinsic quality attributes/process characteristics			0			
Extrinsic quality attributes/labelling	++	+++	+	+++	+	+++
Transparency						
Accuracy	+					
Accessibility and availability	+	+++	+	+++	+	+++
Information sharing	+	+		+	+	+
Quantity of traced information					+	
New themes/measures						
Supply chain governance						
Vertical coordination	+	+		+		+
Behavioural uncertainty	-	-	-	-	-	-
Technological uncertainty	+	+	+	+	+	+
Physical asset specificity	++	+	+++	+	+++	+
Human asset specificity			+		+	
Resources and capabilities						
New knowledge creation	+	+		+	+	+
Capabilities improvement	+	++	++	+		+

Note: 0: no impact; +: increased and code retrieved at least once from the interview; ++: increased and code retrieved at least twice from the interview; +++ increased and code retrieved at least three times from the interview; blank space: not mentioned by interviewee.

Figure 3: The impact of blockchain on the performance of firms

(Source: own.)

Caro et al. (2018) tried to implement blockchain in agri-food supply chain called AgriBlockIoT using Ethereum or the Hyperledger Sawtooth. These decentralized traceability systems guarantee transparent and auditable asset traceability by integrating various IoT sensor devices during agri-food supply chain. Caro et al. proposed a solution based on blockchain technology for agri-food supply chain management, which increases control and trust by achieving transparency, auditability and immutability of the stored records in a trustless environment gathered based on blockchain in the supply chain.

Azzi's group (2019) explained how blockchain improves the supply chain management two Swiss Startups Ambrosus and Modum, by enhancing the transparency and the traceability in the manufacturing supply chain. It is achieved by a policy that focuses on the transparency of the chain, where accurate data collection and secure data storage are required. A good traceability system aims to minimize the production and distribution of unsafe or bad quality products by improving the labeling and racking systems. The track and trace systems have evolved from paperwork to Internet of things (IoT) hardware and sensors.

5 Conclusion

In this paper authors dealt with a disruptive technology of industry 4.0 in a particular sector where the nature of products makes especially valuable the product information. Blockchain is capable to ensure a basis for an innovative, reliable and efficient data management with a shared digital ledger. Blockchain also provides information related to products where come from, products specification, type of product used, harvesting time, and others. With the application of blockchain food supply chains can be shortened in time with waiting time reduction, operation can be traceable, product information can be monitored and shared, food safety and quality can be ensured. By the reviewed blockchain experiences authors could identify benefits which are proved by data and more promises of blockchain can come true by further application.

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