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Review

Blockchain Technology toward Creating a Smart Local Food Supply Chain

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Abstract: The primary purpose of the supply chains is to ensure and secure the availability and smooth flow of the necessary resources for efficient production processes and consumption. Supply chain activities have been experiencing significant changes due to the importance and creation of the integrated process. Blockchain is viewed as an innovative tool for transforming supply chain management's (SCM's) actual business model; on the other hand, the SCM provides an applicative value of blockchain technology. The research is focused on examining the influence of blockchain technology on the increasing efficiency, transparency, auditability, traceability, and security issues of the food supply chain (FSC), with particular attention to the local food supply chain (LFSC). The main objective of the research is to suggest the implementation of blockchain technology in the local food supply chain as a niche of the food industry. The result of the research is the identification of a three-layers model of a smart local food supply chain. The model provides efficient and more transparent tracking across the local food supply chain, improving food accessibility, traceability, and safety.

Keywords: supply chain management; blockchain; local food supply chain; smart model

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1. Introduction

Supply chain management (SCM) activities represent a vital part of the companies' functioning. Considerable changes in the competitive environment can cause difficulties in synchronizing the supply-and-demand processes. Optimization and efficiency of the processes within the supply chain are challenges the technology and business have been encountering. Different digital technologies have provided more efficient, faster, and more flexible processes [1–4]. Transparency issue in supply chains is identified as a source of many problems and difficulties in security, traceability, identity documentation, and verification [5]. Establishing a trust-based environment in supply chains is a significant challenge for implementing effective supply chains [6]. SCM's evolution and digital transformation move toward more connected, smart, responsive, trustee, and transparent tools and systems.

Blockchain-based SCM is considered to reduce costs and increase efficiency [5]. The development and application of new advanced technology cause disintermediation of processes and strengthen trust among the ecosystem's entities and stakeholders. It is a research challenge to examine blockchain technology's actual and potential contribution almost in any economic segment. Blockchain technology should be considered one of the competitive forces of the business environment affecting the competitiveness of the companies [6]. Blockchain may be viewed as an innovative tool for transforming the actual business model of SCM [5,7].

On the other hand, the SCM could provide an applicative value to blockchain technology. Implementing blockchain-based SCM could be seen as a business model innovation

in creating and delivering value among all model stakeholders. Blockchain technology influences changes in all sectors, and blockchains have become the critical element for creating the Digital Supply Chain [8].

Mainly, most of the studies regarding the implementation of blockchain technology focus on the principle of use or the basic model of the SCM and FSC. However, there are no papers or studies about blockchain implementation in LFSC, and we found this to be a research gap in blockchain implementation for study. Therefore, the paper's main aim is to examine the possibility of blockchain implementation in LFSC and propose a model of implementation in the LFSC, representing a niche segment of FSC. The first part of the research shows transmission from the technical aspect of blockchain technology to the application as an added value to the business processes. In the second section, the paper elaborates on the opportunities for implementing blockchain technology in all stages of the SCM. Particular attention is placed on how the blockchain can shift and change the way of handling and coordinating resources, goods, entities, and data. The third part of the research considers the deployment of blockchain technology in the case of food supply chain management. One of today's paramount issues is ensuring healthy and secure food availability. Blockchain technology is an innovative and somewhat unique way that helps the food supply entities and customers to feel more confident about food origin and safety. Blockchain enables all of the entities to see and trust the story behind the food, from the field to the plate. This part recognizes the benefits of blockchain employment in the FSC. The research focused on the blockchain-based coordinated and a linked broad group of food supply chains, including producers of raw materials, manufacturers, logistic companies, brands and retailers, government authorities, banks, insurance companies, and consumers.

The fourth part of the research developed a model explaining the implementation layers of blockchain technology, creating a "smart food supply chain".

The last part of the research presents the narrow adoption of blockchain technology within the local food supply chain—LFSC. Through the LFSC case, the paper explains how blockchain technology can be used to create sustainable competitiveness in the local food ecosystem. The blockchain-based model may be a significant digital shift in the local food network. In this case, implementing the blockchain ensures high quality and sustainable production. Blockchain-based LFSC could be a prototype through which a blockchain ecosystem connects agro-food producers; logistics; and end-users, such as retailers, groceries, supermarkets, the tourist sector, and customers. It presents a blockchain-based model enabling cooperation and coordination in the flow of information, resources, and goods, adding new added value to the local food supply chain. By establishing a blockchain network, the food producers become viable and relevant for the customers and end-users in long-term relationships. The proposed network of linked entities of the local food provides an efficient fulfillment of consumers' needs while differentiating them against the vigorous competition.

The blockchain-based food supply chain aims to improve all processes, focusing on quality, governing activities, product improvement, sales channels, market, consumers, logistics, distribution, and finance.

2. Blockchain and Supply Chain Management

The supply value chains are dominant business models in today's global economy. The supply chains enable companies to increase competitiveness and efficiency by distributing the activities in the most efficient location. The SCM is an integrated system consisting of interrelated subsystems, processes, and activities that continuously should be improved to bring significant enhancement to all parties engaged [9] (p. 158). Its complex process involves several commercial and financial transactions employing many entities, shareholders, information, and documents. Research conducted by Reference [10] showed that companies will need to create a strategy for supply chain digitalization and will need to access new technologies. One of those technologies is a blockchain, for which half of the respondents stated that it has significant importance for further development and digital-

ization of the company's supply chains. Therefore, SCM is seen as a potentially significant area of blockchain application [7,11]. Big multinational companies such as IBM and Maersk started a joint venture for blockchain commercialization in global trade activities [12]. Although recently there have been several reviews of the blockchain literature [13–16], blockchain application in SCM initially attracted only minor research interest [17]. This has changed in recent years, and one can find an increasing number of studies about blockchain implantation in supply chain management [18–20]. Still, the research papers on blockchain implementation in SCM are scarce [21,22]. There are studies about the risk of blockchain use in SCM [23] and the financial contribution of blockchain [24–27]. However, authors [28] stated that there is an increased number of studies about blockchain in SCM.

Further research [29] focused on the data integration in SC with blockchain technology and [30] made the first review of the literature on blockchain technology's potential application in SCM*. On the other side, authors [7,31] used logistics professionals' expert study to explore blockchain technology's potential uses and possibilities in SCM. Furthermore [7] created application clusters of blockchain technology in SCM and logistics from available best practice examples. Finally, [32] concluded that there is no complete viewpoint on using blockchain technology in SCM.

Implementing blockchain technology in SCM will most likely disrupt all industry sectors. Another research [33] presented the relationship between SCM and blockchain technology through the sales process between two companies (producer and supermarket is presented. They presented the sales process between company A (producer) and company B (supermarket). After the sales process is concluded, a contract is recorded, coded, and saved into a blockchain structure. The contract is initiated after the conditions of negotiations are satisfied. Next is transferring the money and goods following the contract. It is essential to state that these activities do not rely on an intermediate. Thus, it speeds up the transaction, promotes cost reduction, and improves trust within the network [33], and all participants in the process have a copy of the ledger [34,35].

Since every network member can access the same data, it fulfills one of the significant blockchain promises—transparency—and provides a single point of truth [36]. Transparency in the supply chain is the most significant thing, but it is the most challenging area for improvement in SCM and logistics [37]. Logistics professionals think that blockchain technology has enormous potential for SCM and logistics [38]. It represents a needed platform for economic revitalization [39], which will change the current supply chains and disrupt how we produce, market, purchase, and consume our goods [40]. When we look at all of the previous studied implementations, blockchain technology can be the holy grail [41] for logistics and SCM.

Nevertheless, as is often the case with new technologies, the push for blockchain is propelled mainly by journalists, consultants, and technology providers [31] since the logistics operators state that they do not have enough knowledge about blockchain [42]. Another research [32] recognized possible blockchain use in logistics based on innovation theory and innovation framework-related characteristics [43], including complexity, compatibility, relative advantage, observability, and trialability. The use of blockchain applications will be in various transformation phases and will need various degrees of consensus and collaboration and regulatory and legislative endeavors [44]. The framework for adaptation can help in blockchain-usage scenarios in SCM based on their originality and organizational effort [45]. Based on that, we can talk about four blockchain application transformation stages: (i) single-use, (ii) localization, (iii) substitution, and (iv) transformation. Based on the potential of the use of blockchain in SCM, there are several potential advantages and disadvantages of blockchain technology in SCM (Figure 1).

The advantages of the blockchain technology used in SCM offer improvement in the current SCM, but at the same time, it creates new ways for how companies deal with their partners in supply chains and how they produce, sell, and deliver products. Additional benefits can be seen in cost reduction since shipment tracking and document management can be stored in a decentralized way, and the information is administered promptly and

available in a timely way [42,46,47]. Table 1 shows several case exemplars of blockchain technology with potential areas where the technology can be used in SCM [31].

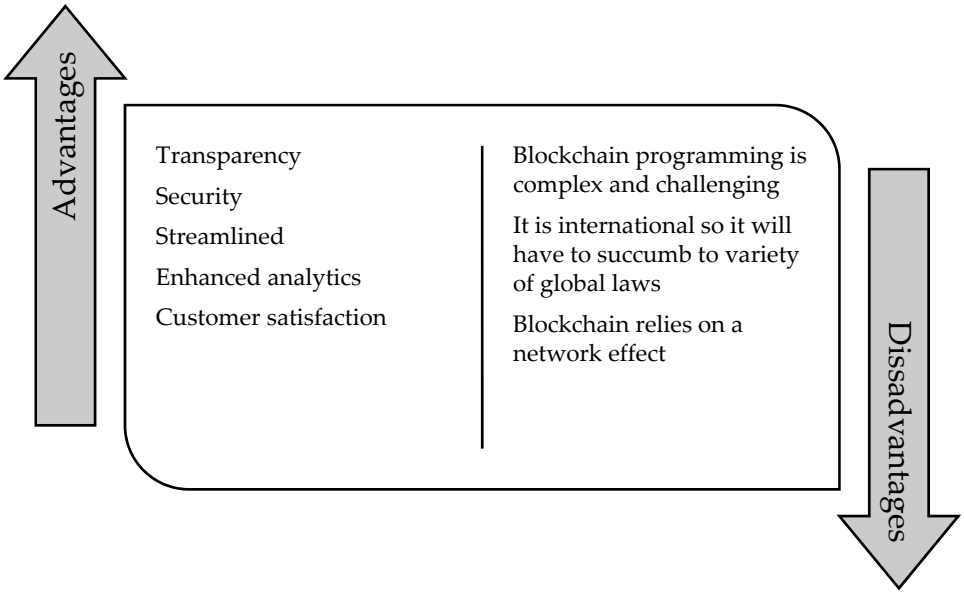

Figure 1. Advantages and disadvantages of using blockchain for supply chain [45].

Table 1. Overview of use case exemplars [31].

Case Exemplars	Description
Ease of paperwork processing	Global container shipping uses a significant amount of paperwork involving costs (money and time). Paper-based documents can be lost, tampered with, and the subject of fraud.
Identify Counterfeit Products	Counterfeit products present a growing problem for supply chains, and companies must sell the right products to their customers.
Facilitate Origin Tracking	In food supply chains, outbreaks related to food present challenges, so the companies need to get quick information about where the food came from, which products are impacted, and from which stores they need to be removed.
Operate the Internet of Things	Recently, many logistic objects had sensors used for generating data in the supply chain, and this information needs to be recorded in an unalterable, straightforward way.

One of the case exemplars of blockchain use in SCM is the food supply chain, where blockchain can increase transparency and help traceability. There are significant benefits of blockchain [31], but a bit less likeness of the adoption of blockchain technology for facilitating origin track, since all the activities through which products have gone are detectable from the production stage to packing and distribution [48].

The blockchain technology potential in the supply chain is confirmed by the top use cases for the blockchain technology survey in 2021 [49], in which supply chain activities have a market share of 10.7%. With the growth of awareness about the opportunities of blockchain technology, the supply chain market is projected to witness innovative and advanced transformation, which enables all participants to obtain access to everything they need on one platform. In 2017, the value of the global blockchain supply chain market was estimated at 93.16 million USD and was forecasted to grow to 9852.91 million USD by 2025. CAGR is expected to grow to 80.2% in the same period [50]. Blockchain applications in SCM practice are gaining momentum, and there are several good practice cases: (i) IBM and Maersk started blockchain joint solution TradeLens for exchanging information and recording effectively transactions [51]; (ii) Kuehne+Nagel started blockchain portal VGM for finishing verified gross weight statements [52]; (iii) Agility created a blockchain solution for tracking and managing container transports [53] (iv) Transport Alliance, the leading body for applying blockchain technology in transport, has now more than 60 members with more than 300 blockchain application [54]. These examples show that if blockchain technology is

successful in the SCM, it will need to gain industry adoption [55]. One of the exemplars of blockchain technology is facilitating origin tracking, leading us to deploy blockchain technology in food supply chain management. This can be achieved by several advantages of blockchain-technology use—transparency, security, and customer satisfaction.

3. Deployment of the Blockchain in the Food Supply Chain Management (FSCM)

Different studies concluded that problems in the food supply chain, including information asymmetry, poor FSCM, inefficient traceability in the food supply chain, and information fraud, can be solved by using blockchain technology [56]. Current technology still did not find the solution for solving these issues. Such is the self-interest of involved participants and asymmetric information distribution [57]. Supply chain traceability and transparency are accessible to companies and end-users in the supply chain. Enhanced transparency can improve competitive advantage through cost reduction and performance [58]. Blockchain technology represents an encouraging solution for improving the company's FSCM. Traceability is usually associated with the security and quality of products, especially in the food supply chain [59–61]. Blockchain technology can be very beneficial for enhancing the supply and security of food since it guarantees transparency to the final customer along the whole food supply chain [62–65]. It can be used for cost reduction compared with traditional systems [66]. Additionally, the delays in warehousing and transport in FSCM can be reduced [67], and RFID can increase the value with its identification possibilities [68].

All current studies [69,70] on implementing blockchain technology in FSCM relate to ensuring food safety and providing a system to manage risks and privacy issues. They found challenges in implementing blockchain technology in the supply chain regarding privacy protection. Since more and more data are stored on the blockchain, a rising concern from the organization and individuals is a potential privacy leakage [71], which should be addressed.

A blockchain-technology-based supply chain traceability system with RFID was proposed for identifying, tracking, and monitoring the entire supply chain through a transparent and traceable platform available for all system members [72]. A similar system based on blockchain was proposed to ensure food products' provenance and guarantee their traceability [73]. This system used the Ethereum platform to create an agri-food supply chain, using smart contracts to ensure the authenticity of Sardinian products. Another study [74] examined storing the relevant data potential of the blockchain technology for food identification. This research emphasized the characteristics of blockchain technology for food-traceability objectives [75], which include quality assurance, proper SCM, and non-compliant product identification. Blockchain technology and smart contracts are excellent tools for supply-chain risk management and improving the system's resistance to confronting cybercrime [23]. Another research study investigated scalability and proposed ProductChain, a generic food-supply-chain framework [76]. Figure 2 presents blockchain-supported FSCM digitalization [77].

Below the documents and goods' physical-flow documents, there is a digital flow that consists of different digital technologies (i.e., RFID, sensors, digital signatures, QR codes, etc.). The whole process is connected through the Internet. Every activity completed in the food supply chain that uses stated digital technologies is documented in the blockchain. The blockchain serves as an unchangeable way of storing information acknowledged by all parties involved in the transaction. The information obtained during every transaction is proven by food-supply-chain business partners and establishes a consensus between all parties. After the validation of each block is finished, the block is added to the transaction chain as a permanent part of the whole process.

Blockchain technology implementation in FSCM has several barriers, but, at the same time, it offers many potential benefits for the whole chain [77] (Table 2).

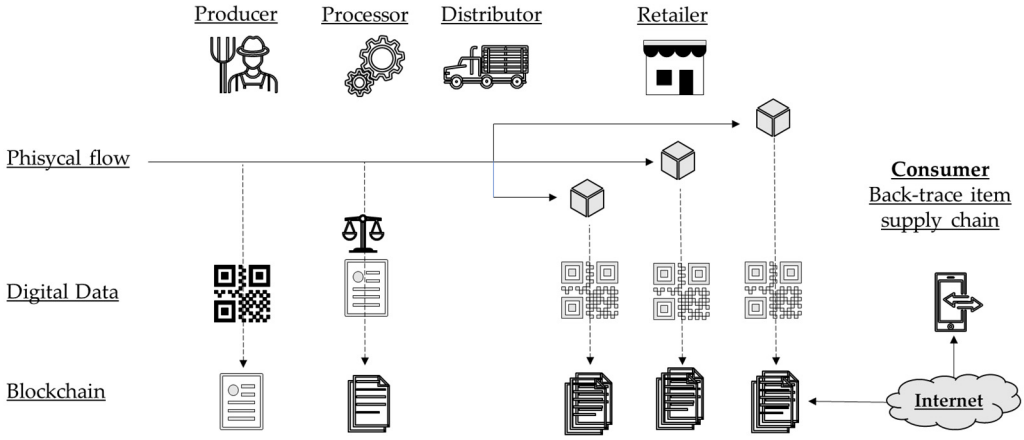

Figure 2. Blockchain in FSCM [76].

Table 2. Benefits and barriers to blockchain use in the food supply chain [77–82].

Potential Benefits and Opportunities	Existing Barriers and Challenges
Value chain traceability and origin	Difficulties in technology adopting
Better pricing in the value chain	Technical and scalability issues
Reduction of transaction fees and smaller intermediaries' dependence	Infrastructure and cost challenges
Transparent transactions	Law and regulation challenges
Empowerment of customers	Food systems' nature challenges
Increased quality of products	High volatility of cryptocurrencies
Lower probability of foodborne diseases	Privacy issues
Reduction of waste and increased sustainability	Challenges regarding knowledge and skills
Customers have more information for purchasing decisions	Non-existing ecosystem for blockchain implementation

Based on Table 2, it can be concluded that there are many potential benefits and opportunities for the implementation of blockchain technology in FSCM. However, technology faces different challenges and barriers.

In practice, several surveys have shown the potential of blockchain application in FSCM. The potential of blockchain technology used in the food and agriculture market global market value should grow from $32.2 million in 2017 to $1.4 billion by 2028. Between 2018 and 2028, blockchain in the agriculture and food market in Europe is projected to grow 42.85% annually, by 40.42% in North America, by 7.85% in Asia-Pacific, and by 48.33% in the rest of the world [83]. After testing blockchain technology in FSCM, 12 of the worldwide biggest companies started their projects to redesign how food is traced around the world by using blockchain technology [46,84]. Walmart, Nestle, and IBM are among those companies. The new US Food Safety Modernization Act requires companies to increase traceability possibilities to "one back, one up". The current way of handling this process is challenging and takes time. With integrated blockchain technology, the information needed would be found in minutes, not days or weeks. Some of the other current tests of blockchain technology in FSCM include Walmart and Hyperleadger Fabric for tracing the origins of mangos and pork [85]; IBM Trustchain tracks tomatoes from farm to table [86]; and SAP and Bumble Bee Food are documenting Indonesian tuna-fish products with the help of blockchain [87]. Although the previous examples focus on product traceability, companies want to influence third parties to provide more information and value to the ecosystem (i.e., food safety issues, food fraud, and food waste) [84]. Further examples of products and blockchain implementation objectives are shown in Table 3.

The abovementioned examples reveal the increased attention of food manufacturers to the reliable products' documentation blockchain. Besides the food manufacturing companies, examples show that large IT companies have also shown interest in blockchain technology for FSCM. Previous food scandals influenced food producers to generate a competitive advantage by securing trustworthy origin proof [79]. That leads to the point that implementing blockchain in FSCM can increase the confidence of consumers [85].

Thus, leaders in the industry should look at blockchain technology in FSCM as a prospect, and it should be included in the digitalization strategy presently influencing the whole food industry [63].

Table 3. Products and blockchain-implementation examples [77].

Objectives	Goods/Products
Traceability	Turkeys, mangoes, canned pumpkins, pork, Beer, beef, cannabis, chicken, chestnut trees, seafood, organic food,
Financial	Soybeans, grain, olive oil, organic food
Faster operations	Soybeans
Supervision and management	Grain, sugar cane, table grapes, water, rice
Animal welfare	Turkeys
Environmental impact	Seafood
Waste redirection	Food waste

4. Blockchain Model of Food Supply Chain Management (FSCM)

According to the World Economic Forum, blockchain is a shared, programmable, cryptographically secure, and therefore trusted ledger that no single user controls and can be inspected by anyone [88]. The food supply chain (FSC) encompasses many participants, including producers (farmers), processors, manufacturers, certifying agencies, government agencies, intermediaries, government agencies, logistics, distributors, retailers, and customers. Any of these members of the FSC generate and disseminate information and record the product or transaction that they create. The implementation of blockchain technology is disrupting the ways of managing and operating such a comprehensive system such as FSC. Through the blockchain-based recordkeeping model, all participants of the FSC may access all products and transactions. It provides a secure environment where the data cannot be modified once entered and verified [89]. Thus, the information regarding manufacturing processes, the origin of raw materials, implemented standards, and delivery terms are available and can be verified by the shareholders of the FSC. The blockchain works as a shared book of records in which any participant can access the product's provenance. For example, all participants in the supply chain of cheese can view the production and logistics processes the final product has been passing from the farm to the consumer plate. Blockchain technology enables the untrusted parties to reach a consensus on a common digital history. A typical digital history is important because digital assets and transactions can be easily faked [90]. Blockchain-based FSC creates traceable and irrevocable records of all transactions in real-time, providing ultimate visibility to all members along the supply chain. The blockchain-based model of FSC can be analyzed in three layers (Figure 3):

1. Business model layer;
2. Platform layer;
3. Application layer.

The business model layer summarizes the main elements of the FSC ecosystem. It represents participants, goods, supply-side lead time, customer order time, inventory management, and stock-out [91]. Participants consist of all stakeholders involved in producing, enabling, supporting, inspecting, and making reliable the flow of the goods to the table. Food is a specific type of good that often gets worse in value and quality over time. The variety of food products is broad, ranging from those with a very short supply chain to those that have to pass through several processing steps before eating. The lead time is an essential part of the FSC business model layer, which varies significantly on the food type. Governing the lead time can diminish the uncertainty in the supply and demand of food products. A crucial element for reaching higher efficiency and irrevocability of the business model layer is to locate the responsibility of any participant of the FSC. In such a complex environment, it is challenging to determine who has processed what type of data and where and when the transaction and processes are happening. Thus, the application

of blockchain technology can contribute to the management and governance of FSC as a comprehensive system to be shifted to an upper level.

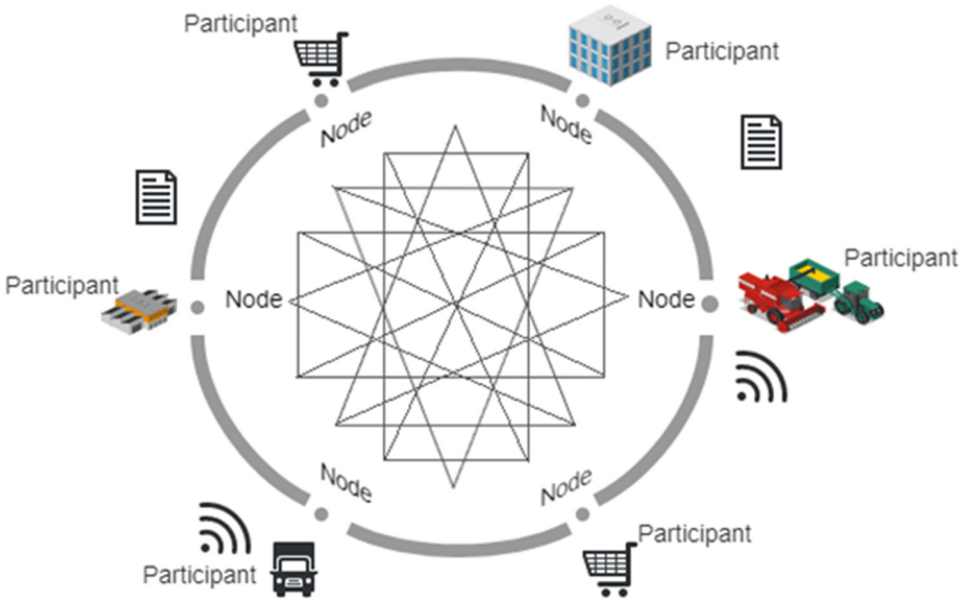

Figure 3. Three-layer model of blockchain-based FSC (source: authors).

The platform layer provides a technological framework consisting of the blockchain platform. Since the blockchain is a shared, distributed, and immutable transaction ledger [82], the platform layer represents the blockchain transaction mechanism, leading to the transaction transformation. Any transaction forms a block as it appears. A transaction block contains context information such as the source, date, and time, ensuring transparency, traceability, and immutability. All the nodes or computers distributed around the blockchain network verify any block. Each node maintains a copy of any block, resulting in a unique history that is impossible to be modified. The blocks are linked in a string of chains, wherein any block is linked to another block by a hash of data of the previous block. So, the hash conveys the information from the previous block, proving that information or documents have not been altered over time and that the documents have owned someone in a certain period [92,93]. For example, suppose that there is a dispute about the amount of ordered and delivered goods in a transaction. In that case, dispute resolution could be reached by validating the original document in the previous block with the next block's hash. Any transaction feature ranging from documents, photos, signatures, time, or location data is hashed and written to the blockchain [88].

The application layer provides additional functionalities not available at the platform layer. The most practical applications used in the FSC are smart contracts and IoT. Smart contracts provide additional value to the blockchain-based FSC. They are computer programs holding the terms of a contractual arrangement and implementing the agreement, while ensuring trust, transparency, and understanding between parties [92]. Smart contracts are embedded in the blockchain, and they ensure the automation of many transactions without the involvement of any intermediary. They are intentionally helpful in solving the inter-parties' lack of trust activities, such as logistic activities and financial transactions in the FSC. The IoT consists of embedded sensors and communication capabilities to a physical object, providing an opportunity for monitoring, communicating, and tracking the condition or status of the food. The stock's conditions and locations could be directly registered on the blockchain [94]. These transactions could be sent and recorded automatically on the blockchain. For example, once the stock packages are loaded, the smart devices register the transaction on the ledger, communicating the information to the buyer to fulfill the financial obligation or customs clearance activities. In the other case, the smart devices

can evaluate the sanitary condition of the food by communicating with the sanitary officials to inspect.

The multitier nature of the FSC, engaging various stakeholders, is challenging for improvement of the chain governance regarding the unfair trading practices, trustiness, cooperation, and transparency. The proposed model for blockchain-based FSC represents a valuable general framework for adopting blockchain technology for any food.

5. Case study—Improving Competitiveness of Local Food Supply Chain Using Blockchain

Blockchain technology has the potential to address a variety of FSCs. It can respond to the requirements of the FSC regardless of the geographical distance and complexity of the supply chain, enabling improved communication among the participants, traceability of activities, and transparency of transactions and data. The local food supply chain (LFSC) is a kind of FSC where the blockchain implementation could be considered a solution for competitiveness strengthening of the local producers. Local food represents food and beverages with a local identity, distinctive origin, or unique qualities related to the production method, tradition, or raw materials [95]. The LFSC includes relationships between food producers, distributors, retailers, and customers. Local food producers usually offer small-scale healthy, premium quality, handcrafted local food products. Since they are small family producers with limited production volumes and negotiation power, their access to the market is complicated. Figure 4 represents three tiers of blockchain-based food supply chains implemented on the local food supply chain.

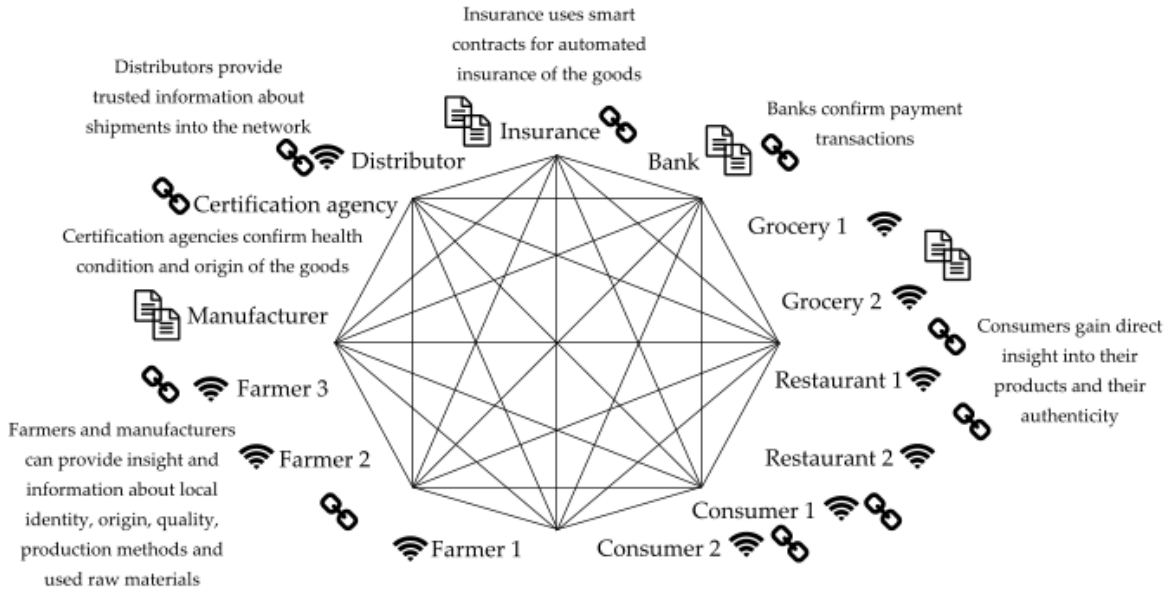

Figure 4. Implementation of blockchain technology in LFSC (source: authors).

The local food value chain starts with the players, inputs, or products and handles their flow to the final customers. Efficiency can be improved if products flow faster, safer, transparently, immutably, and trustily through the value chain. Handling food is a challenge, especially locally produced food. It is related to unique features such as the seasonal character, whether it is handcrafted, and lead times. Additionally, food represents a material sensitive to the influences of the external and internal environment and limited durability influencing the quality. The employment of blockchain technology as a governing solution creates a new business model with a collaborative approach of all the players who become an integral part of an ecosystem of shared risk. LFSC can be designed as consumer-to-business (C2B), business-to-consumer (B2C), and business-to-business (B2B) models, meaning that individual farmers (producers) or businesses can be enabled to offer their products in the value chain. The target customers or end-users of the model may be retailers, individual customers, caterers, and the tourist sector. The other players

represent logistic services and support institutions such as governmental agencies for veterinary, sanitary control, banks, local community, and consultants' agencies. Blockchain in the LFSC delivers a new environment for sharing data where competitors can cooperate. Blockchain will enable the participants to identify any bottlenecks and problems by sharing the information between the participants. It helps regarding effective asset utilization; optimized facilities location and warehouse activities; and efficient storage, picking, and packing activities.

The functionality of the blockchain-based LFSC model is represented by a decentralized distributed system that collects and records the information about any transaction arising. Automatically, in real time, a secure and shared record for any activity of each product journey is created. When a new transaction is performed, i.e., picking the food by the carrier, the ledger automatically records the context information about that transaction. It allows the network to create an immutable, chronological, and transparent order of entries for the product [96]. All LFSC participants can know the provenance, real-time location, and status of their food products at any point in the supply chain, providing proof of the origin.

On the other hand, consumers can acquire information about food ingredients from the farm to the finished products, product details, and ingredient sourcing information. For example, research on coffee drinkers reveals that most prefer to buy sustainably grown and responsibly sourced coffee. The blockchain technology behind IBM Food Trust allows drinkers to trace their coffee from farm to cup. By scanning the QR code on the coffee package, the consumers pull information directly from the blockchain. The IBM Food Trust connects a user to farmers, traders, roasters, and brands, allowing each product to tell a story [97].

According to the Food Industry Forecast, 84% of consumers want to buy local, meaning food sourced within 150 miles [98]. Inefficient food supply chains generate a large amount of food waste/loss during harvesting, storage, transportation, preparation, distribution, and consumption. Twenty-five percent of all foods transported in the cold chain are wasted in the food supply chains due to breaches in integrity, causing temperature fluctuations and product degradation [99]. Distribution is one of the biggest challenges for small-scale local food networks. Producers, especially from the rural areas, are challenged with the distance-demanding transport, product handling, food security and quality control, labeling, and document issues.

Blockchain solutions drive visibility and transparency through the entire supply chain and empower communication and collaboration across the ecosystem. It enables better handling of perishable goods through real-time supply chain data for product location and temperature through delivery. Blockchain enables end-to-end supply chain visibility, reducing the time needed to trace a food source, ensuring knowledge about the health status of the food, and preventing waste. Food safety and quality are essential to the company's internal processes and brand reputation. In that direction is the IBM solution for tracking the temperature at which the beef is kept during the journey from farm to fork. IoT devices monitor the temperature at strategic points in the process and automatically deliver information to the IBM Food Truck's Blockchain [100].

The relationship based on trust and loyalty between the producers and the customers is critical for the LFSC. Branding, packaging, quality, and the identity of the food to a particular region influence the value of the product or service of the LFSC. Blockchain-based LFSC may ensure visibility and trust across the supply chain, resulting in consumers' sustainable quality and brand differentiation. For example, one of the largest olive oil producers who produce the extra virgin oil brand Terra Delyssa has implemented a blockchain to prevent oil fraud and mislabeling. The company uses blockchain to share the origin and production process with consumers. By scanning the QR code, the consumers can see the farm where the olives come from, view certification and testing documentation, and learn about the olive oil's traditional making [101].

Groceries represent an essential chain of the LFSC. The blockchain platform provides an opportunity to decrease operating costs and increase competitiveness against fierce competition. It leads to more customer-oriented groceries. More American customers are willing to pay up to 36% more for products that are responsibly made and transparently sourced [101]. Thus, the implementation of blockchain technology provides customers with information that helps with buying decisions referring to the origin, ingredients, quality, and manufacturing process. The experience of Carrefour is confirming sales-boosting by the use of blockchain ledger technology in tracking meat, milk, and fruit from farms to stores, thus increasing customer trust. By scanning the QR codes on the food label or packaging, the customer can access information such as the location of growing, harvest date, packing date, safety tests, and certifications [101].

Critical stakeholders of the LFSC represent the catering and restaurant sector. Being part of the blockchain platform enables restaurants to share the provenance and journey of ingredients with the guests. By sharing the information about the food they offer to the consumers, the blockchain can help build brand trust around quality, safety, sustainability, and sourcing of ingredients. For example, by scanning the QR codes on restaurant menus, guests may be provided access to the blockchain platform to acquire information on how the ingredients used in the dish were harvested and handled as they moved down the supply chain from the farm to the plate. It is essential because most guests research the restaurant online before deciding. Today, people want to know where their food ingredients have come from [102].

The functionality of the blockchain-based LFSC is enabled and supported by the application tools that enable the automation of business decisions and real-time notification about the food journey along the supply chain. Smart contracts can automate many of the costly and time-consuming processes. Exceptionally, they can automatically provide proof of delivery, authorization of payment, confirmation of the condition of goods, monitor expiration dates, certification, and insurance. Since local food is related and sourced from a specific location, organic and traditional production process, the blockchain application tools ensure data for commodity provenance, tracking growing and processing conditions following the food safety standards. The solutions such as the Internet of Things (IoT), smart contracts, and RFID technology provide information to the decentralized ledger, which is accessible to all nodes of the network. IoT devices monitor local food's growing conditions and processes and fuel the blockchain-based LFSC. They collect and transmit traceability data about the farming environment (soil, water, temperature, and humidity), farming staff, date, time, origin, and application of pesticides [103]. Collected data are then fed into the blockchain system, where the other participants have access. Due to this, chain members can transparently trace the status of food products upwards and downward in the supply network.

The blockchain-based LFSC ecosystem provides exceptional visibility into how the local food is handled through production and the journey along the supply chain.

6. Discussion

Benefits related to blockchain technology promise a bright future and enormous opportunities for the supply chain as a business model. It is a challenge to examine and analyze the opportunity of implementing blockchain technology in managing the local food supply chain—LFSC. Blockchain technology in the LFSC was not previously researched, and this presents a novelty in the blockchain application. Most research focuses on blockchain-based supply chains, analyzing the global food chains. Local food could be considered a niche segment with specificity related to the size, type of food, the players, and the environment of influence. Consumers' interest in local food has increased sharply in recent years. Interest in local foods accelerates various potential benefits, including economic, environmental, health, food safety, and rural development [104].

The paper reveals a new value and dimension in applying blockchain technology in the local food supply chain. The paper identifies opportunities for blockchain technology

as a sustainability innovation not uniquely in the basic FSC but very successfully and efficiently in LFSC. The paper is alongside the previous studies suggesting that blockchain technology is an advanced solution for enhancing traceability, trust, transparency, and reducing fraud. Respectfully, the paper focuses on one niche segment of the food industry, i.e., local food. This segment represents a massive challenge for research, since the local food is considered a source of healthy food where the customers' trust is counted as the highest priority. Accordingly, the blockchain implementation in the LFSC could be considered a tool, upgrading the benefits positively to all the chain participants. To the producers, it opens an opportunity to be integrated into a chain with higher transparency, equal treatment, and automated fulfillment of agreements. Blockchain-based LFSC may be very helpful for establishing collaboration and coordination between rural farmers. They are facing the problem of selling their goods to wholesalers, retailers, or supermarket chains because of limited production volumes and higher prices than large producers. Additionally, blockchain technology may contribute to more cost-efficient distribution solutions for delivering food products from farmers to the end-users.

Against the benefits assumed from implementing the blockchain technology, the main challenge represents the adoption of this technology. The main issues concern the technology readiness, knowledge, and willingness of the stakeholders to enter the project of technological shifting. Furthermore, from the financial aspect, blockchain could increase the transparency of the food supply chain, but its usage comes with some financial costs [105]. The farmers or small- and medium-sized firms with limited technological expertise and financial resources may encounter the inability to adopt blockchain [106]. Moreover, the other challenge is related to the efficiency of governance since the LFSC could take a range of various forms of organization and selling arrangements between producers and buyers, different forms of interaction between consumers and producers, and different levels of commitment from consumers [107].

Finally, the last vital item to be solved or secured regarding blockchain implementation in LFSC is a privacy issue. As we previously stated, there is a concern for potential privacy leaks, and this concern needs to be addressed before more companies consider implementing blockchain in their LSFC. Blockchains have several privacy types in their systems (transaction data privacy, state data privacy, smart contract privacy, and user privacy). Reference [70] stated that permissionless blockchain systems back none of these privacy types since they provide maximum pseudo-anonymity. Thus, the authors proposed using permissioned blockchain systems as a potential solution. Reference [108] proposed a privacy-preserving approach for preventing potential information leakage in IoT, but this approach can also be applied to the blockchains in LFSC. Their approach offers vital improvements in privacy protection in different possible scenarios, and based on their research, there is a possibility of preventing potential privacy leakage. Similarly, Reference [109] presented a blockchain framework devised for increasing smart objects' autonomy and protection. The second framework addressed several potential privacy-attack scenarios and offered potential solutions to privacy leaks. The issue of privacy protection can lead to reputation and economics loses and slow down further e-commerce innovation if it is not managed correctly. Reference [110] proposed a blockchain-based mechanism for personal privacy, used as an application scenario in online taxi-hailing. Other possible solutions include Hawk [111] for protecting privacy without storing the clear text of blockchain, Obscuro [112] for secure and efficient Bitcoin mixer, and Ouroboros Crypsinous [113] for analyzing the privacy protection in PoS protocols. Reference [114] concluded that homomorphy encryption and code obfuscation techniques could be a promising direction for ensuring privacy protection. Previously mentioned solutions and frameworks can be used in the proposed LFSC blockchain model. The solutions mentioned above add value to increasing privacy protection against potential information leaks, but they need to be tested within the model.

Balancing benefits and challenges will be the future directions in blockchain technology research as an advanced digital tool. Since it is not just essential to create and invent a new

technology, it is more critical to provide applicative value to the technology and implement it in an existing or new business model.

7. Conclusions

Competition in the food industry today is immense. Brand differentiation, uniqueness, innovation, and sustainability are drivers of consumers' loyalty and buying decisions. Today consumers want to know any issue about the food they eat, and they want to know the food's origin, how it was grown, and in what conditions. People prefer to consume local food that is grown in a healthy and clean environment, traditionally produced without adding artificial ingredients and pesticides. The local food supply chain is challenged to put in place a system that will track any activity in the value chain. The paper focuses on adopting blockchain technology for governing the local food supply chain—LFSC. It is a pioneering attempt to analyze the adoption of a blockchain in a narrower and specific supply chain such as local food. The paper reveals that blockchain technology may contribute to and provide the benefits essentials for the LFSC, such as ensuring more stable supply and demand for the local food and better coordination and communication between the players, ensuring food safety, freshness, and quality of the brand and preventing chances for fraud activities. Within the paper are observed some experiences which confirm and justify the adoption of the blockchain technology as an efficient mode of governing the LFSC.

The importance of the LFSC is considerable and needs to be recognized by the different economies, so that they start to pay special attention to supporting these business models. The EU has set a strategic approach to the local food systems. The "Farm to Fork" Strategy (F2F) of the EU is designed intentionally for a fair, healthy, and environmental-friendly system focused on enhancing the food system's economic, environmental, and social sustainability. It is considered an opportunity to reshape supply chain dynamics and deliver improvements for all participants [115]. The F2F strategy is oriented toward transforming the EU's s food system by 2030, but it misses a technology of achieving that objective. Blockchain technology may be considered a promising technology in ensuring efficient and sustainable management of local food supply chains.

Blockchain is a promising technology for a transparent supply chain of food. However, many barriers and challenges still exist that hinder its wider popularity among farmers and food supply systems. The near future will show if and how governmental and private efforts could address these challenges to establish blockchain technology as a secure, reliable, and transparent way to ensure food safety and integrity. The LFSC will need to address potential blockchain privacy leak issues, which is also one of the obstacles to its broader use. Assessing a potential approach to securing privacy protection is one of the possible directions for further research on implementing blockchain in LFSC.

The limitation of the paper is also a potential for future research. Blockchain technology in the local food supply chain is present only in several examples worldwide, and they were shown in the paper, which is a significant limitation of this paper. On the other side, this also represents a potential for future research. We could test our models in practice and try to see the potential of implementation of blockchain technology in the different parts of the world (i.e., East and Central Europe, Africa, Latin America, etc.)

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