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Blockchain, Quo Vadis? Recent Changes in Perspectives on the Application of Technology in Agribusiness

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Abstract: Information technologies such as blockchain are developing fast, overcoming bottlenecks, and quickly taking advantage of their application. The present study analyzes recent changes concerning the benefits, disadvantages, challenges, and opportunities of blockchain applications in agribusiness. Interviews were conducted with and a questionnaire was applied to professionals working in the development and application of blockchain technology in agribusiness, to compare their perception of the recent advances. The results showed that the importance of blockchain technology to improve governance and information flow along supply chains has increased, and this is the main perceived benefit. The main disadvantages were removing intermediaries and the high cost of implementing the technology. The absence of a widely accepted platform in blockchain operations is the leading and growing challenge, while patterns for blockchain technology seem to be being overcome. The integration of blockchain with new technologies, and the competitiveness provided by the technology, are seen as the main and growing opportunities. Despite the study limitations, we conclude that the benefits and opportunities associated with blockchain application in agribusiness outweigh the challenges and disadvantages in number and importance, and are becoming more relevant.

Keywords: trust; transparency; immutability; profitability; sharing data; business models; symmetry of information; traceability; transaction costs; smart contracts

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1. Introduction

Blockchain is a relatively recent technology that is rapidly developing. In its trajectory, several obstacles have been overcome to enable its application in different sectors of society. Initially, this section recalls relevant aspects of blockchain technology's background and presents the research question that guided the present study.

1.1. Background

In 1991, Haber and Stornetta [1] proposed a method for date and time stamping digital documents. However, digital documents cannot be time-stamped or authenticated in the same way as paper documents. At the time, the authors proposed a basic structure consisting of hash cryptography (algorithm) that organizes immutable information into linked blocks. An authentication service organizes the documents or blocks of information sequentially, according to date and time.

The spreading of encrypted information among different clients (companies or people) guarantees that recorded data cannot be altered without leaving traces [2]. In this flow of information, first, if a client wants to falsify previously registered information,

the authentication service can check the previous record and identify the fraud attempt. Second, suppose the authentication service itself conspires with a forger to try to falsify previously recorded information, in that case, he/she cannot do it without leaving traces, since the information is distributed among the other clients that will be able to audit the forgery [1]. In other words, even if a client and the authentication service are dishonest and act together to create fraud, the other clients can identify it. So, the technology works like a logbook that can keep permanent data records about decisions and transactions [3]. Since it is composed of blocks of information in a chain, the technology started to be called the 'blockchain'.

Blockchain technology is becoming efficient, robust, and cost-effective for managing interactions between multiple participants in a network, in a very reliable and decentralized manner [4,5]. Likewise, it facilitates the use of information by subsidizing demands and providing the real-time updating of records. It also increases supply chain transparency and product or service traceability by allowing the exchange of transactional data between two or more actors in the chain [6]. This is because data stored in the blockchain is reliable and cannot be deleted, altered, or corrupted, without most parties involved in the transaction being aware of the changes.

Blockchain is considered a significant technological trend that could influence business in general, as it is a disruptive solution for several business segments capable of increasing the trust of bilateral or multilateral relationships [6]. Thus, blockchain could create competitive advantages in many business sectors, especially agribusiness. Rocha et al. [7] point out several blockchain applications in agribusiness activities, such as finance, energy, logistics, environmental management, agriculture, livestock, and agro-industry. According to the authors, blockchain can be successfully implemented, and applications for logistics can result in energy, financial and environmental advantages.

Agribusiness comprises long supply chains involving various economic sectors, and fundamental activities such as providing food and energy for the human and animal populations. As end-consumers seek more information about product quality, origin, and mode of production, company managers, supply chains, and governments, are pressured to adopt solutions that ensure product transparency and traceability [8,9].

In agribusiness, blockchain technology can be applied in solutions to ensure the security and traceability of products in a system in which information is transmitted between all links and actors along the value chain. Information sharing allows for building trust and transparency between actors. Consumers can trace products to check their origin and production mode, hindering the possibilities of product counterfeiting and adulteration [7,10]. Thus, a traceability system based on blockchain brings benefits and information to all those involved in the supply chain, including the final consumers [11–13], since it enables the use and exchange of data in a secure, transparent, and effective manner [14].

By integrating blockchain, IoT, and wireless sensor networks, the end consumer can track the product, verifying its origin, harvest date, mode of transport, and certification, increasing consumer confidence in the product they are purchasing. Consequently, technology can increase the demand for these products among those consumers who value such information [15,16].

The information recorded by the blockchain is secure and can be publicly or privately accessible, depending on the preferred strategy, and most importantly, it is immutable. This allows the information to be accessible to retailers, auditors, governments, consumers, producers, and other stakeholders along the supply chain. Moreover, it provides for monitoring and auditing the data, assessing economic and environmental performance, or other indicators of interest [17]. Additionally, blockchain has the advantage of eliminating dependence on a central authority. Its decentralized nature elevates the importance of the network effect. The technology's potential benefits increase as the network's size expands, making it more robust against external attacks [18].

Finally, the interoperability of blockchain and the use of mobile devices, from computers to smartphones, put the power of decision-making in the hand of consumers [19].

However, the benefits and opportunities associated with using this technology and the advantages and disadvantages it provides to stakeholders influence managers' decisions to adopt blockchain [20]. Furthermore, business models need to rebuild existing systems, popularize the technology, and train staff to adapt to the new management process [21,22].

1.2. Research Question

Due to the numerous advantages of blockchain technology, its development and applications have advanced rapidly. For example, Arooj et al. [23] identified that in 2017 blockchain technology was at the crossing chasm stage when the industry was adopting proofs of concept, funding was being provided by venture capital, and issues related to scalability, sustainability, and throughput, were resolved. Three years later, in 2020, blockchain reached the adaption movement stage, characterized by the definition of standards and protocols, an explosion in the use of blockchain, funding by specialized IT companies, the use associated with IoT for the development of smart contracts, and use in e-government solutions. At the current stage, blockchain is in use for major banking application shifts, forcing changes in banking infrastructure, IoT applications, and AI-based smart contracts.

Therefore, in a short time, blockchain technology has evolved from proofs of concept into practical applications in several sectors. As a result, several authors address the adoption of blockchain in agribusiness [24,25]. Still, more studies analyzing the perception of actors involved in the application of blockchain in agribusiness over time are needed.

For this reason, the present study analyzes this recent evolution from the following research question: What changed in the perception of professionals involved in the application of blockchain in agribusiness regarding the benefits, disadvantages, challenges, and opportunities of the technology in recent times? Thus, the objective is to analyze the recent changes in the benefits, disadvantages, challenges, and opportunities of blockchain applications in agribusiness from the perspectives of experts.

The adoption and impacts of blockchain technology on agribusiness supply chains follow the same pace as other sectors and can be affected by successive events in a short time. Thus, the perception of benefits, disadvantages, challenges, and opportunities can change relatively briefly. Identifying the benefits and opportunities that have increased their relative importance may indicate remarkable stimuli to promote technology development and adoption along supply chains.

On the other hand, disadvantages whose relative importance has increased signal weaknesses of the technology that need to be strengthened to make blockchain affordable and competitive. Identifying opportunities whose relative importance has increased reinforces aspects that can be prioritized in the search for gains related to the development and use of blockchain technology. Therefore, by achieving the objective and answering the central question of this research, we hope to bring contributions to the various actors interested in the development and adoption of blockchain technology along supply chains, such as developers, farmers, industrial managers, logistics operators, financial system, regulators, and consumers.

2. Materials and Methods

In answering the research question proposed in this study, the methodology was divided into two phases and classified into two approaches. The first phase considers exploratory and qualitative research (Figure 1). In this stage, interviews were conducted with Brazilian experts who are somehow involved with the development and application of blockchain technology in agribusiness. The interviews sought to understand the perception of experts about the benefits, disadvantages, challenges, and opportunities of blockchain technology in order to qualify the objective answers.

A semi-structured interview script was used to collect information from experts and researchers on blockchain technology (See Supplementary Material S1). The script was designed based on the concepts found in the literature reviewed. Interviewees needed to

understand blockchain technology, its structure, and the agribusiness sector. The semi-structured interviews allowed the interviewer to steer the questions in the direction best suited to the agribusiness context.

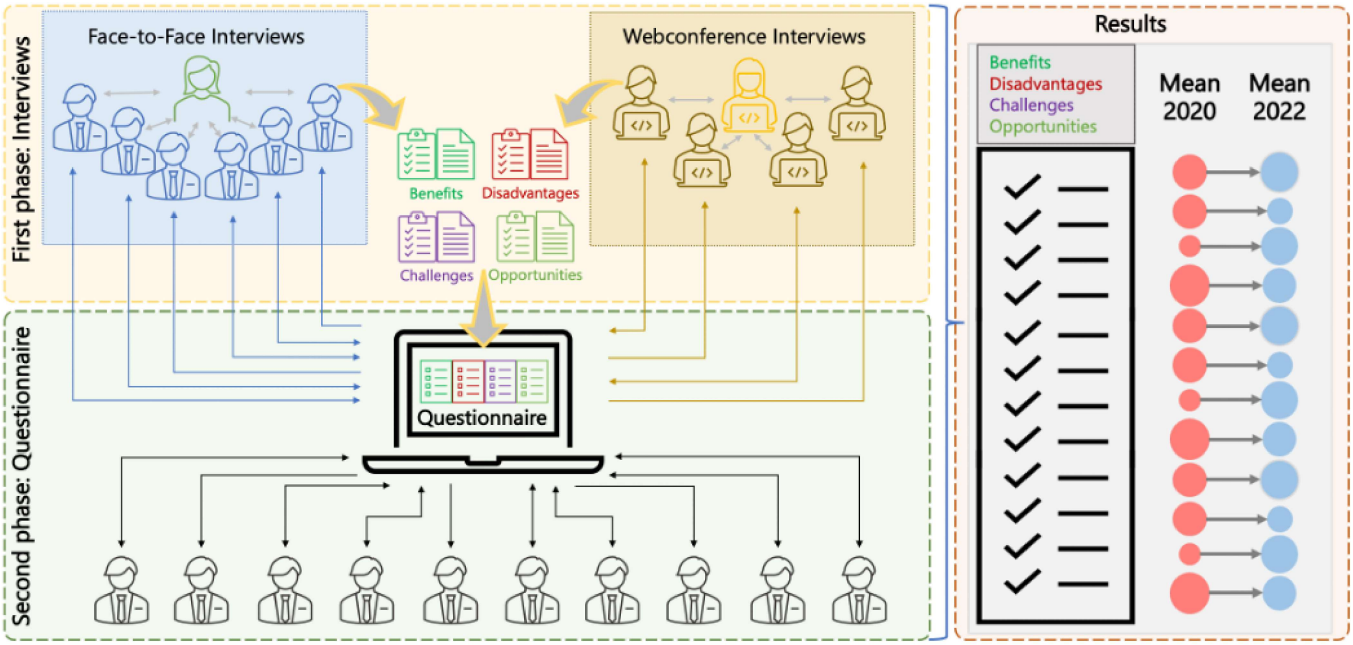

Figure 1. The framework of methodological phases and procedures carried out in the research. Source: elaborated by the authors.

The interviews were conducted with 10 specialists, six in person and four remotely via web conference (Skype), in January 2020, with an average duration of 50 min. After the interviewees' permission, the interviews were recorded and later transcribed in a text editor to be analyzed. The respondents are managers, coordinators, developers, or researchers with knowledge of programming, technology, and business models. They were collaborators from many companies and universities. All interviewees were involved in blockchain technology development or implementation activities or were university researchers with research projects on the topic (see Table 1).

Table 1. Profile of the professionals interviewed in the first phase of the research.

Expert	Education and Background	Working on . . .	. . . at the Organization
1	Electrical Engineer, MSc and PhD in Computer Science	Computer networking and security	Universidade Federal do Rio Grande do Sul—UFRGS, Institute of Informatics and Graduate Program in Computing
2	Economist and MSc in Business Management. Background in Risk Management, Foreign Trade and International Business, Alternative Energy	Support to a multidisciplinary group of specialists	Blockchain Collaborative Institute—ICoLab
3	Accountant, MSc and PhD in Administration—Systems Management and Information Technology	Accounting and information system	Universidade Federal do Rio Grande do Sul—UFRGS, Accounting Department
4	Economist, PhD in Economic Development, Space and Environment	Applied economics.	Universidade Federal do Paraná—UFPR, Departament of Economics

Table 1. *Cont.*

Expert	Education and Background	Working on . . .	. . . at the Organization
5	Lawyer, MSc and PhD in Law Science	Public International Law, International Economic Law, Economic Criminal Law, and International Criminal Law	Ulbra University and Graduate Program in Law at UniRitter University
6	B.A. and MSc in Computational Mathematics. PhD in Computation Science	Blockchain researcher	IBM (São Paulo, SP)
7	B.A. in Data Processing, MSc in Applied Informatics	Innovation and technology entrepreneur	Park Hub and ONE Percent Software Innovation Studio
8	Accountant. MSc and PhD in Administration—Information Systems and Decision Support	Costs and management information systems research	Universidade Federal do Rio Grande do Sul—UFRGS, Faculty of Economics
9	B.A., MSc, and PhD in Administration	Digital transformation, enterprise mobility, cryptocurrencies, and Blockchain	UNISINOS, UniRitter, UFRGS, Feevale, ICoLab e ONE Percent Software Innovation Studio
10	Ecologist, MSc in Civil Engineering (Water Resources), PhD in Economics, and Post-doc in Cryptocurrency Design and Alternative Economic Systems for Planet Regeneration	Collaborating professor at the Institute of Economics at Unicamp University and entrepreneur	Unicamp University and Satisfied Vagabonds (Costa Rica)

Source: elaborated by the authors based on research data.

The interviews were analyzed using content analysis techniques. First, the content of the interviews was grouped into categories related to the benefits, disadvantages, challenges, and opportunities of applying blockchain technology in agribusiness. Subsequently, this information was used in preparing a questionnaire with a Likert scale to be applied in the second methodological stage of the study.

The second phase of the research was quantitative, and the information collected via interviews was organized into a questionnaire with a Likert scale. The questionnaire was developed in a digital platform and sent to the personal e-mail of the 10 experts who had participated in the interviews in the first stage (January 2020). The response rate was 60%, considering six experts answered the questionnaire in October 2022. In addition to the experts who participated in the interviews in the first phase of research (interviews), the questionnaire was also forwarded to other experts who were somehow involved with developing and applying the technology in agribusiness, and seven responses were obtained.

All the participants (first and second phases) were invited to express their perceptions of the benefits, disadvantages, challenges, and opportunities related to blockchain applications in agribusiness. For each benefit, disadvantage, challenge, and opportunity proposed in the questionnaire, all the participants should assign a Likert value considering the importance of the respective item at the beginning of 2020 and another value (1 = lower, 3 = equal, or 5 = higher) considering the importance of the same item at the time of completing the questionnaire (October 2022).

The purpose of the questionnaire was to quantify the experts' responses by capturing the change in their perception regarding the benefits, disadvantages, challenges, and opportunities of applying blockchain technology in agribusiness. Thus, we calculated the average of each item of the four axes under analysis: benefits, disadvantages, challenges, and opportunities, in order to compare the averages between the years 2020 and 2022. Based on the mean values, figures with the main results were prepared, presented, and analyzed in the next section.

It is emphasized that, in Brazil in general, and in agribusiness in particular, the existence of experts and companies working in the development and applications of blockchain technology is still restricted. Nevertheless, the experts were identified and invited to participate in the research on their evidence in blockchain research and development, availability of contacts, and willingness to contribute, justifying the low number of participants.

3. Results and Discussion

3.1. The Realms of the Benefits, Disadvantages, Challenges, and Opportunities of Blockchain

Experts were asked about blockchain benefits, disadvantages, challenges, and opportunities for agribusiness. The interviewees presented different points of view according to their areas of expertise. Thus, the interviews were analyzed, and the essential items were highlighted in Table 2.

Table 2. Experts' opinions about the benefits, disadvantages, challenges, and opportunities of blockchain technology.

	Item	Why? Experts' Opinions about the Items
Benefits	Reduction of transactions costs	The authenticity and trust provided by the blockchain reduce the agents' insecurity and consequently minimize transaction costs.
	Better governance and information flow	Blockchain allows governance by convenience. In the first step, each party involved does not need to share all their information or data, but only what matters and with each need.
	Smart digital contracts	Smart contracts can perform operations, such as executing financial transactions or authenticating documents in a common legal agreement. This will make everyday business less bureaucratic, as it will decentralize operations.
	Trust, transparency, and immutability	Blockchain technology makes production chains more transparent, as information is recorded and auditable in a decentralized manner.
	Optimization of resources and processes	The adoption of the blockchain platform will speed up bureaucratic processes, which is reflected in the optimization of resources overall.
	Greater profitability	Adopting the blockchain platform will give speed to processes, higher quality in records, reduced transaction costs, resource optimization, and increased profitability.
	Information on the network visible to everyone	Blockchain improves trust in contractual relationships as long as the information on the network is verified by all participants, eliminating the need for a trusted third party.
	More security throughout the production chain	Supply chains need to be more integrated. So, blockchain will help the whole process, integrating all actors, from the producer to the consumer.
Disadvantages	High cost of technology implementation	Currently, there is a high cost to develop and implement blockchain technology.
	High maintenance cost	There is a high cost of maintaining and storing information for operationalizing blockchain.
	Elimination of intermediaries	The intermediaries' elimination could break the links in the supply chain by monopolizing production and excluding many people from the production process.
	Absence of a single blockchain technology standard for different business models	No robust, global platform can be found that stands out. As a result, different solutions are being developed to address specific problems.
	Lack of a winning platform	The solutions developed for specific problems have not allowed for establishing a widely accepted platform, code, or universal solution.
Challenges	Collect, process, and store data	As blockchain technology becomes widespread, vast amounts of data will be generated. Moreover, many copies of the information are distributed among users, requiring big storage and processing capacities.
	New business model generation	Creating decentralized businesses is still counterintuitive. Nevertheless, blockchain enables the creation of decentralized and autonomous networks, directly integrating the end consumer and the farmer.

Table 2. *Cont.*

	Item	Why? Experts' Opinions about the Items
Challenges	Break with old paradigms	Breaking with old paradigms will be a challenge because it means changing society and the way people are used to doing things.
	Skilled labor	Specific software engineers are vital players in the advancement and spread of blockchain.
	Lack of a winning platform	Many pilot projects are in the early stages of application, such as IoT Blockchain, Bitcoins Blockchain, Rapper Ledger Blockchain, and Corda Blockchain. An integrative and widely accepted platform is not available.
	Intermediate elimination	The farmer can transfer the product directly to the final consumer so that the technology will exclude intermediary actors from the supply chains, which could create serious social problems.
	Quality of information entered on the network	The information inserted incorrectly in the network, either by some fault or by bad faith, may be out of touch with reality.
	Absence of blockchain technology standards	There are various attempts and initiatives, each with positive features and challenges.
Opportunities	Integration with new technologies	Blockchain has the integrated potential to store contact information, financial information, and logistics information securely and audibly.
	Product traceability and certification	Transparency about the products' origin, processes, and inputs can be updated in real-time, allowing the consumer access to product information.
	Digitization of the production chain	The possibility of improving the efficiency of overall processes can leverage the digitization of end-to-end supply chains.
	Information symmetry	All actors involved may have access to important information. However, all info may be available according to a strategy agreed upon by traders.
	New domestic and foreign markets	Blockchain guarantees the final product in terms of transparency and certification of its origin. In addition, higher levels of confidence allow new buyers to access markets.
	Competitive edge	Innovation in agribusiness has already proven to bring benefits. The blockchain platform will be able to automate many processes, increasing standardization and quality and leading to competitive advantages.
	Product differentiation	At first, safety and traceability will be a differentiator for consumers.
	Product standardization	The exchange of information and the automation of processes will lead to greater standardization of the production process.

Source: elaborated by the authors based on research data.

The benefits relate to the advantages or good things that blockchain can do for agribusiness and society. Similarly, the opportunities are more related to favorable circumstances for developing and implementing blockchain in agribusiness. On the other hand, the challenges represent the impediments to blockchain development. Finally, the disadvantages are problems that blockchain might generate.

Many of the explanations made by the experts are in line with data found in scientific literature. For example, the possibility of reducing transaction costs occurs because blockchain may solve many supply and demand matching issues. This will be made possible by the symmetry of information between consumers and suppliers [26].

In this same sense, smart contracts can significantly contribute to the governance of organizations. With blockchain, deals can become decentralized, and transactions can be executed with smart contracts and virtual currencies [27]. In other words, contracts and

payments can be executed and settled automatically according to parameters agreed upon in advance by the parties. Human action will be required only at the time of negotiations.

Following the same perspective, trust and transparency among negotiating actors can lead to more efficient use of resources. Blockchain may secure information sharing while maintaining the privacy of those involved [28]. This integration improves efficiency in resources such as time, people, and others. Thus, even if the efficiency gains are short-lived, the new technology allows rethinking processes associated [29].

However, sometimes the experts were at variance with the literature. According to one expert, adopting technology will have a chance of reducing gains from some actors or eliminating them from the supply chain. The intermediaries' elimination could break the links in the supply chain by monopolizing production and excluding many people from the production process. On the other hand, since blockchain simplifies processes by dispensing with intermediaries involved in contracts for goods and services, parties can control tangible or intangible material damage by sharing access data [30]. So, depending on the point of view, eliminating intermediaries can be an advantage or a problem. A technology that is good for business may not necessarily be good in social terms.

Regarding the disadvantages and challenges, using blockchain may require sharing data by partners in a supply chain. In this sense, some partners may feel insecure when sharing information, and data loss and hacking by those involved may also occur. Furthermore, it may imply that anyone can have access to private information, leading to the non-participation of some actors in a blockchain network [31].

These results are in line with the findings in the study by [32], who highlighted important points that may affect the adoption of blockchain in the agricultural sector, such as lack of regulatory guidelines adopted by the government, security issues of technology, lack of awareness among actors, blockchain complexity, resistance to change by collaborators, trust between parties involved in the network, and high investments in technology development.

As blockchain technology is recent, it still requires large investments in infrastructure and maintenance, given the lack of specialized labor for its development. Given this, there is a need for employee training for blockchain adoption.

Blockchain has also faced several security challenges, mainly in digital assets blockchain systems, which the experts did not point out. However, according to the literature, Sybil attacks are becoming frequent and challenging to prevent, with several fake nodes being possible on a blockchain network [33]. Such a situation can lead to a non-acceptance of technology on a large scale. Iqbal and Matulevičius [33] explored this subject in more detail and proposed a framework based on the domain model for security risk management to explore Sybil and double-spending risks in blockchain systems. The model illustrates the assets protected or to be protected and the classification of threats that the attacker can unleash using the Sybil attack, which causes double spending on blockchains.

Gopalakrishnan et al. [34] argue that implementing a blockchain platform can involve high development costs, depending on the strategy and the intended solution. However, the opportunity to reduce transactional costs can make the technology viable. For example, Niforos [35] estimates that the operational costs of supply chains account for two-thirds of the final cost of goods. Therefore, processors, distributors, and consumers can benefit from reducing these costs via blockchain implementation.

On the other hand, some agribusiness services and activities may cease to exist since automation may remove intermediaries. Consequently, the blockchain follows principles like those applied in implementing Bitcoins, where open access and removing intermediaries are critical features of the technology [6].

3.2. Changes in Experts' Perceptions about Blockchain from 2020 to 2022

In general, the experts believe that most benefits have become more important over almost three years (Figure 2A). Only the benefit of more security throughout the production chain has maintained its importance between 2020 and 2022, and this is the benefit with the lowest importance score. The benefits with the highest importance scores in 2020

were reduced transaction costs and improved trust, transparency, and data immutability. Reduced transaction costs remained the benefit with the highest importance score in 2022, accompanied by enhanced governance and information flow. However, the main change in perspective concerns the perception that blockchain technology enables better governance and information flow along supply chains, whose perceived importance score increased by +15.4% (3.9 to 4.5). The second and third largest relative changes in perceived importance relate to achieving greater profitability in activities (+11.1%) and the possibility of drawing up smart digital contracts between actors in supply chains (+10.2%).

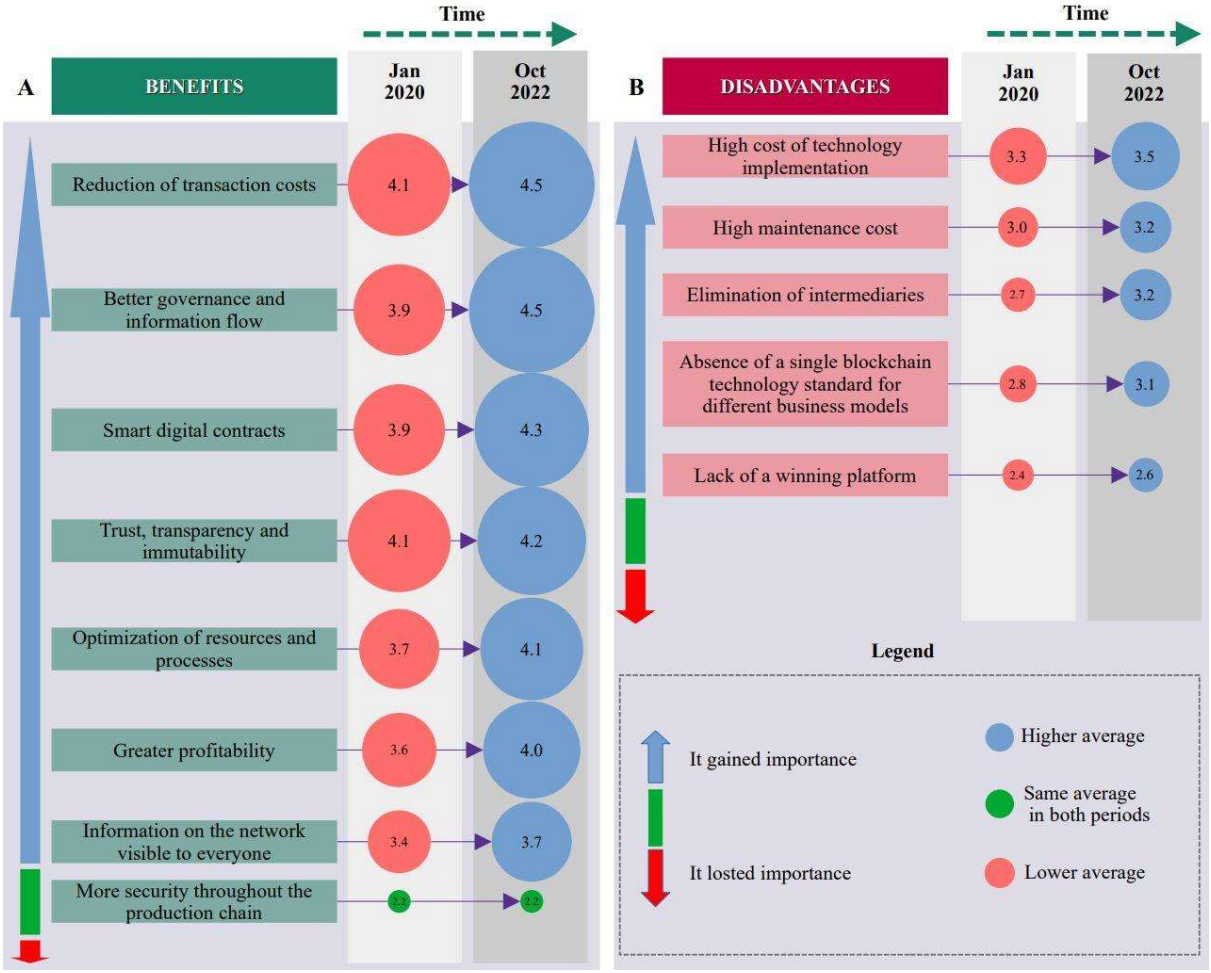

Figure 2. Changes in perceptions of the benefits (**A**) and disadvantages (**B**) of applying blockchain technology in agribusiness. Source: prepared by the authors based on survey data.

All disadvantages gained importance in the period. Blockchain implementation and maintenance costs were pointed out as the main disadvantages of the technology. The elimination of intermediaries as a negative result of adopting the technology had the highest percentage growth, 18.5 percent (score from 2.7 to 3.2).

The experts listed more and attributed more importance to the benefits than the disadvantages in both periods. During the interview, the experts also pointed out that blockchain technology will reach farmers through public, private, or cooperative initiatives. The interviewees also pointed out that farmers may seek to collaborate to drive the modernization of activities, showing optimism about the adoption of blockchain in agribusiness.

The benefits (Figure 2A) suggest more secure and transparent relationships among supply chain members, including final consumers. Experts believe that direct connections between producers and consumers can be established, reversing the current commercial logic in which intermediary actors have great power of governance in supply chains. In

other words, aspects of supply and demand will become more transparent, and market speculation movements may be accessible to all actors in the supply chain, making markets fairer and less speculative.

Besides benefits and disadvantages, there are challenges and opportunities for adopting blockchain in agribusiness. Therefore, there are bottlenecks to be overcome and incentives to be explored in the technology development and adoption process. According to the experts' perception, all opportunities have become more critical in the three years (Figure 3B). The possibility of integrating blockchain with new emerging technologies was highlighted as the foremost opportunity. Traceability, certification, and supply chain digitization are among the top opportunities for technology adoption. On the other hand, the opportunity with the most significant variation in perception was a competitive advantage, with an increase of +17% (score from 3.0 to 3.5). In the same direction, information symmetry and product differentiation were the second and third opportunities with the most significant variation in perceived importance.

As the transactions carried out in a supply chain were placed on a blockchain, the information would be symmetric among actors since they could access it in real time. Therefore, a blockchain can be seen as an opportunity to record data with better reliability. In this sense, the competitive advantage is provided by technology's possibility of total and rigorous control of all chain stages. Furthermore, it promises to establish the automation of production processes, configure greater transparency, providing agribusiness sectors with greater business opportunities with new international markets. In the same direction, information symmetry and product differentiation were the second and third opportunities with the most significant variation in perceived importance.

Data collection, processing and storage, and the creation of new blockchain-based business models ranked as the top challenges for the technology (Figure 3A). They were the second and third items with the most significant change in perspective (11%, from 3.7 to 4.1). Meanwhile, the leading absolute change in perspective was related to the lack of a dominant or winning platform, with a 17% increase (2.3 to 2.7). Additionally, breaking old paradigms is also considered important for technology development and use. Finally, the possibility of eliminating intermediaries in business and the quality of the information entered into the systems are challenges that have remained stable during the period.

The experts pointed out that supply chain actors must restructure how they record information. At a later stage, current business models may be replaced, and information recording may become a major challenge. Sharing sensitive information requires the collaboration of many players, and some intermediaries may be hampered by technology. Influential intermediaries may hinder technology adoption or try to monopolize information to preserve their position, maintain profitability, and sustain their competitive advantage. In the future, the way of doing business will change, and some players may no longer be needed, as some interviewees reported.

On the other hand, the current supply chain cycle is considered long and inefficient, leading to the continuous deterioration of product quality and food safety [36,37]. From addressing this weakness arise many opportunities for digitizing information with reduced costs and significant improvement in input and food flows. Among several opportunities, the potential application of blockchain is associated with the ability to keep reliable records available and auditable to all stakeholders, including end consumers. Furthermore, proper blockchain design makes it impossible to alter recorded data without the consent of all involved. Therefore, blockchain can dramatically reduce transaction costs, as insecurity is almost wholly removed. Blockchain technology also makes supply chains more transparent and more efficient information flow between links. Future scenarios indicate that blockchain solutions are expected to be widely adopted and supply chains computerized to meet the aspirations of Industry 4.0.

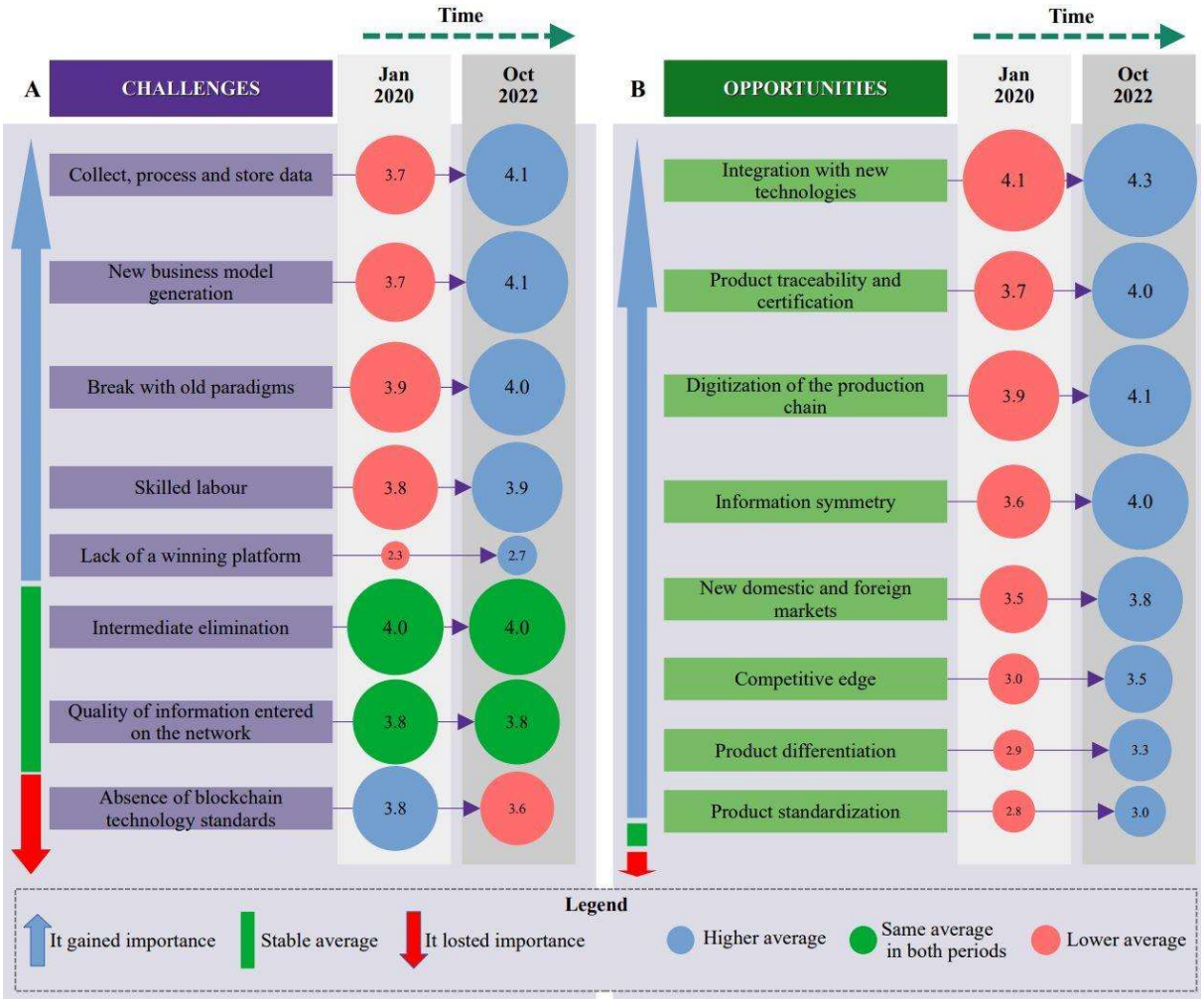

Figure 3. Changes in perceptions of the challenges (**A**) and opportunities (**B**) of applying blockchain technology in agribusiness. Source: prepared by the authors based on survey data.

Responses from the interviewees indicate that in 2020 blockchain technology was still in its early stages of development and its impact on the economy is not yet noticeable. However, it is believed that advances in the development of technology will change the way economic agents relate to each other, transforming the flow and exchange of information and contracts both domestically and globally and transforming the economy as a whole [38]. Our findings in the present study already signal that advances have occurred in this brief, almost three-year period.

Blockchain will be like a decentralized database. Everyone involved in the supply chain will be responsible for feeding, storing, and maintaining real-time information to allow transactions to be made and completed simultaneously [39]. The decentralized nature of the technology elevates the importance of the network concept, and the potential benefits of the technology increase as the size of the network expands [26]. In this context, business models need to rebuild existing systems, popularize the technology, and train personnel to adapt to the new management process [22,40].

Furthermore, interviewees perceive that the novelty of blockchain technology may impact the trust of the parties involved in a smart contract. However, human-computer interaction techniques can help build this trust [34]. The globalization of trade has forced supply chains to expand their nodes and relationships, involving diverse entities and complex transactions that cover a wide range of geographic places. As a result, farmers, entrepreneurs, consumers, logistics companies, media, financial institutions, industry

associations, and governmental regulators, could be connected by blockchain through smart contracts, automating records, reducing transaction costs, and reducing risks of contract fraud [41].

4. Conclusions

At the end of the analysis, the following were the main changes observed in the perception of professionals regarding the development and application of blockchain technology in agribusiness:

(a) Experts believe that blockchain technology has been consolidating the promise of delivering benefits for supply chain management since it improves governance and information flow, facilitates the creation of smart contracts, reduces transaction costs between actors, and increases trust, transparency, and immutability in the sharing of information.
(b) Eliminating intermediary agents in transactions and high costs for the implementation and maintenance of blockchain have been the main disadvantages, signaling that the level of competitiveness in the blockchain market still offers opportunities for new entrants.
(c) Generating new business models and collecting, processing, and storing data are challenges to be met by overcoming old paradigms, especially concerning information sharing. In addition, other challenges are being overcome, such as establishing standards for technology while eliminating intermediaries, qualifying the information added to the network and the workers' skills, and developing a platform capable of integrating the other blockchain initiatives that seem to be constantly advancing.
(d) Finally, integrating blockchain technology with other emerging technologies, especially the IoT, digitalizing supply chains' information, guaranteeing symmetrical access to information, and enabling to trace and certify products are seen as increasing opportunities.

Therefore, we conclude that blockchain and its application to agribusiness present the fast development characteristic of any emerging information technology, with several potential uses. In almost three years, the perceptions of professionals working in this field are that most of the benefits of blockchain have grown in importance. In opposition, fewer disadvantages have been identified, with a slight increase in perceived importance. Thus, the benefits of blockchain outweigh the disadvantages in number and importance and are perceived as more relevant.

Similar perceptions were observed regarding opportunities and challenges. At least three challenges were perceived as less important in 2022 than in 2020, suggesting the perception that the development of blockchain technology has been able to overcome some bottlenecks perceived as critical not so long ago. On the other hand, all the opportunities considered in the study have increased their perceived importance. We can conclude, therefore, that the perception is that: first, the development of the technology has been overcoming the challenges; and second, the possibilities of blockchain applications in agribusiness have strengthened the belief that they can generate many opportunities.

Our conclusions are limited by the number of professionals participating in the study and cannot be generalized. Blockchain is still an emerging technology, and its development and implementation depend on several players and variables. At the current stage of blockchain development and adoption, it is impossible to predict the real impacts that technology may have on agribusiness. Future studies can focus on mapping the fundamental variables for technology development and their effects on supply chains, business, and the possibility of removing actors from supply chains. Finally, major changes can occur in agribusiness due to technologies such as blockchain, and researchers can explore these transformations by proposing appropriate solutions and avoiding adverse developments. The threat of cyber-attacks, for example, was not addressed in this study but deserve attention in future studies.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/fi15010038/s1, Supplementary Material S1: Script for the interviews with Blockchain experts.

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