Streamlining Management in the Agri-Food Sector through Blockchain Technology

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Abstract

Industry 4.0, innovations and digital technologies in agricultural development are considered the main criteria meant to increase the efficiency of production activity in this branch and to propel economic development to a higher level. The researches in the area of Agriculture 4.0 alongside Industry 4.0 increasingly address digital technologies such as cloud, platform, robotics, artificial intelligence, Internet of things and blockchain to the sustainable development strategies and growth policies of many countries around the world. Sustainable development in agriculture through digitization involves the development of new management models based on information technologies to improve efficiency on farms, soil conservation and biodiversity by minimizing the negative impact on the environment, ensuring a stable level of production and profit. The present research aims to investigate the notion of blockchain technology and capitalize on this technology to streamline the management in the agricultural sector. The paper is a study of international experience and good practices of digital technologies tenders in the agri-food sector.

Keywords: Industry 4.0, blockchain technology, digital agriculture, agri-food sector, management efficiency.

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1. Introduction

In recent decades, humanity has witnessed unprecedented growth and development. According to international forecasts, the world's population will reach 9.2 billion by 2050. Food and Agriculture Organization of the United Nations (FAO) states that farmers need to produce 70% more to meet the growing demand for agricultural products of the population. However, progress in the world economy causes environmental pollution and the depletion of natural resources. The current pattern of growth and mismanagement of natural assets could ultimately undermine human development.

Current working conditions, global crises and pandemics are forcing producers to use new agricultural models instead of traditional ones to maintain sustainability in agriculture. Globalization, which affects including the agricultural sector, imposes a new strategic vision on the digitalization of agriculture.

The agricultural sector has been following technological developments and has benefited from these advances for many years. Developments in satellite, GPS (Global Positioning System), GIS (Geographic Information System) and other mobile communication technologies have led to the emergence of precision agriculture. Especially in recent years, the development of information and communication technologies such as cloud computing, Internet of things, artificial intelligence, robotics and big data analysis allows the launch of the fourth industrial revolution in agriculture.

Digital technologies are the future of the agri-food industry, and attempts to ignore them are hampering the agriculture development.

The Internet of Things, robotics, artificial intelligence and large volumes of data are applied by farmers around the world and contribute significantly to streamlining production processes.

Technological innovation in agriculture is an essential part of the solution. Agricultural technologies, in particular, have the potential to increase the productivity and sustainability of agriculture. Research in the field considers digital technology - the only realistic way to meet current challenges.

Sustainable development of the agricultural sector is identified as one of the primary strategic development priorities of the Republic of Moldova and is crucial for ensuring economic growth. The agricultural sector, as a share of gross domestic product, ranks second after the services sector and ranks first in terms of contributing to economic growth. However, the productivity of the sector remains at a deficient level is determined by the lack of available investments and loans, the application of low-yield technologies.

For a long time, the agricultural sector was not of interest to the "new generation" of farmers and investors. Climate risks characterized the agriculture, lack of automation and innovation, and the implementation of information technologies in agriculture was limited to using computers to manage finances and monitor business transactions. Today, modern technologies have evolved and are intensely introduced into the practice of the agricultural sector, offering high-performance and efficient solutions. Historically, the economy has climbed several stages of development, and today it reaches the fourth stage, which we can call digital, for the simple reason that it operates with information processing and technologies. Namely, IT technologies become usable in the traditional spheres, which, as a result, acquire new qualities and advantages.

The development of internet technologies, communication channels and digital platforms has forced the emergence of public information systems and global industrial networks beyond the particular boundaries of enterprises. By interacting, these systems and networks have a transformational impact on all areas of the contemporary economy, leading to a new era of industrial automation, the fourth industrial revolution.

Being a political, economic and social provocation for the whole world, Industry 4.0 absorbs digital innovations in products, processes and business models. Many developed countries in Europe, America and Asia have included the concept of Industry 4.0 in their strategic growth programs for the coming decades, seeing the digital economy as the basis for future prosperity.

Business leaders and global manufacturers accept digital challenges and opportunities as a conceptual leapfrog of new realities generated by technical and scientific progress.

At the same time, the criteria for evaluating the performance of transformations in Industry 4.0 are still little studied, and the structured and systemic implementation of these technologies in national economies for many countries is not fully finalized.

Cloud computing, automatic results control, work agreement optimization will generate; consequently, the management efficiency growth in all the activity areas. The concept of digital agriculture now means water-saving agriculture, smart agriculture, high-quality, and high-efficiency and non-polluting agriculture. In the view of many authors, digital agriculture is the most effective and necessary approach to achieve all these transformations by using computing and communication technologies to increase profitability and sustainability in agriculture.

The digitalization of agriculture is a new direction to increase the efficiency of the agri-food sector and sustainable development of the entire economy.

2. Literature review

Contemporary researchers highlight several directions for implementing modern technologies and approaches in agriculture.

Investigated theme in the present paper was addressed in policies and strategies for sustainable development and implementation of digital technologies in the economy and society of European and international bodies. There are visions on Industry 4.0 and Agriculture 4.0 in the works of internationally renowned economists (Shwab, 2016; Christiansen, Yüksel, 2017; Deichmann, Goyal, Mishra, 2016).

Several authors (O'Grady, O'Hare, 2017; Adnan, Nordin, 2018; Young, 2018; Trendov, Varas and Zeng, 2019) studied the digitalization of agriculture as a necessary condition for the economic growth and population welfare in developing countries.

The proposed solutions for streamlining management in digital agriculture belong to the application of blockchain technology in Agri-Food supply chain management by Caro, Ali, Vecchio and Giaffreda (2018). Tian (2017) recommends using blockchain to ensure food safety in the supply

chain traceability system. Boehm, Kim and Hong (2017) studied IT security applications and products traceability in the agri-food sector.

Other research refers to the benefit created by blockchain technology in the production of particular crops: wheat (Lucena, Binotto, Momo, and Kim, 2018), soybeans (Hoffman and Munsterman, 2018), sugar cane (Chavez-Dreyfuss, 2018) and table grapes (Ge, Brewster, Spek, and Smeenk, 2017).

Good practices in blockchain technology experiences in agri-food sector examined in research can serve as a valuable example for these practices implementation on a large scale, to ensure the competitiveness of domestic agricultural products.

3. Data and methodology

To support scientifically the presented ideas and recommendations, the author made a literature review of the publications on the issues of innovation and quality improvement of the agri-food sector in the digital era. The modern concepts of Industry 4.0, digital agriculture, blockchain technology were used to argue the value of IT technologies in agriculture sustainable development. The research examines the World Bank, and United Nations Food and Agriculture reports on agriculture development, and the pilot projects and reports on blockchain implementation in agri-food supply chains management.

The author uses monographic methods, comparative and systemic analysis, case study, as well as a logical approach to the trends of world economies in the light of the development prospective of the Republic Moldova economy.

The authors analyze the path of agri-food chain to consent the blockchain technologies to increase the management efficiency. The dynamics of agricultural sector development are addressed as an integral part of the country's economy. According to factors that have a situational impact in the current period of activity: trends in agricultural management development, introduction of innovations that positively affect socio-economic indicators development and the environment, increasing

employment and income, financing mechanisms for the agricultural sector and the financial results obtained.

4. Blockchain technology concept

Nowadays, internet communication is a necessity and, although this development has opened up new opportunities, the problem of trust between people has become considerably more pronounced, which has now reached its critical level in business. The underlying currency of trade is trust in the business partner, and each transaction includes the availability of data that characterizes the partner from a legal and financial point of view.

Thus, to be able to trust the business partner, we must check the history of the transactions made by him or the existing financial data about him.

In response to the problem of mistrust, in 1991 Stuart Haber and W. Scott Stornetta developed the concept of the cryptographically secure blockchain, known today as Blockchain Technology (Beyer, 2018). Following the financial crisis of 2008, this concept was developed as a solution for securing financial transactions made through various institutions, organizations and economic entities.

Blockchain technology is a database that maintains a dynamic list of records. This algorithm allows encryption of transactions with public keys, accessing them with private keys and general distribution of the entire resulting log. A decentralized journal, which cannot be altered and which does not depend on a central entity.

In the financial field, blockchain technology works as a universal accounting system, which can increase the efficiency of the accounting process of economic transactions and operations. System ensures confidence in the provenance, certainty, and fullness of the rights and obligations of the parties to the sales.

Blockchain is a fundamental change in the way financial records are created, maintained and updated. With a single owner, blockchain records can be assigned to all users. Moreover, the value of this system is to spread unique data about transactions made to all interested users, regardless of their origin.

Blockchain technology is a back-office solution for transporting possession of materials and recording data online - in other words.

Over the last three years, blockchain technology has seen an explosion of interest in potential applications in the financial, industrial and social sectors from businesses and research institutions. This technology is still in an early stage of development, with considerable potential for all areas of activity.

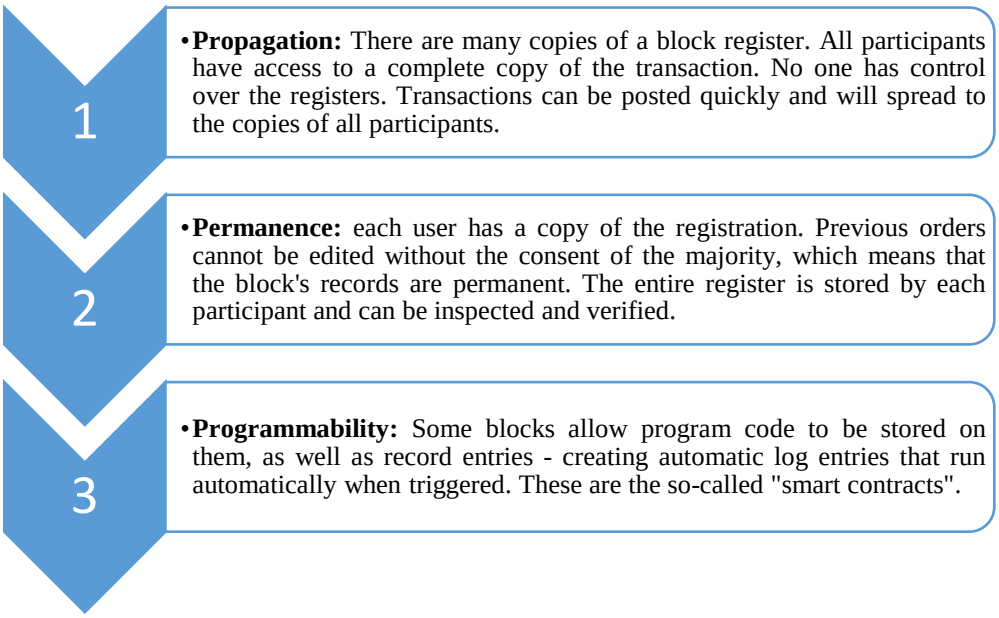
In the Netherlands, industrial interest in blockchain technology was first documented in late 2014. Several Dutch banks began their first modest experiments with bitcoin payments. As this technology has progressed beyond bitcoin, it has become clear that blockchain can be applied not only in financial transactions, but also to secure many other types of information transactions. Subsequently, blockchain technology was tested for a broader range of Dutch financial services (insurance, pensions), logistics, energy, healthcare, telecommunications, industrial manufacturing and more (Ge et al, 2017).

The significant aspects of blockchain technology are summarized in "three Ps" - three key terms that explain how the blockchain operates and what makes it different from existing software. The key features of blockchain technology are presented in Figure 1.

Blockchain is not a single technology, but rather a protocol - a way of thinking, perceiving and conducting business - for recording transactions, based on an advantageous cost, synchronization, security and the certainty of having a consensus with business partners. Unlike the Internet, where data is shared, ownership of the data can be transferred from one side to the other without the possibility of modifying previously recorded data. For example, in a multi-traded market, any participant in the register can track previous transactions, achieving increased transparency and permanent control of registered operations.

Conceptually, blockchain is a move from the trust in financial documents certified by the auditor, to the situation in which the faith derives from the system that performs the registration. Smart contracts allow for a programmable registry that could fundamentally change the way all agreements work.

Figure 1. The key features of blockchain technology



Source: *Adopted by author after ICAEW, 2018*

The blockchain as a control technology has a vast potential. Private blocs between groups that often trade with each other could replace central authorities, such as banks, supervisory bodies and experts. Eliminating uncertainty benefits the economy by streamlining it, facilitating greater confidence in decisions.

Besides, where appropriate, a tax authority, a regulatory authority or a similar supervisory body may be granted exclusive access to access such a block and may observe and monitor transactions in real-time. This type of agreement could lead to a reduction in costs and an increase in the efficiency of regulatory and compliance activities. The blockchain reduces the chances of financial crime, making recordings more reliable.

The five main benefits that blockchain technology offers are:

1. Protection of rights
2. Creating a distributed economy
3. Elimination of taxes
4. Data protection and control
5. Compensation for producers

The outcomes of implementing blockchain technology in management will determine the automation of regular functions, significantly reduce internal and external fraud and strengthen the reliability and usefulness of financial information. Effects on decision-makers also include automating and improving the security of transactions.

6. Blockchain technology experience in Agri-food sector

The latest research and projects applied in the field of Industry 4.0 show that agriculture is a thriving area for blockchain. In the Netherlands, farmers and agri-food suppliers use this technology to find a solution for many management problems what characterize agriculture transactions. The Italian scandal over fake "organic cereals" in 2011, the "horsemeat burgers" crisis have undermined consumer confidence across the European Union and highlighted the failure of EU member states to regulate subjects related to proper food chain checks. Moreover, the ongoing problem of food certification authenticity are some relevant examples. Blockchain technology facilitates data exchange and reduces opportunities for fraud or adultery. In the UK, the social enterprise *Provenance* became a leader for certification of agricultural products through the blockchain application. Other areas for blockchain are tracking, improving trust in data sharing and securing. In this way, the management of the agri-food chains is more transparent and efficient.

Another good practice is "*Blockchain for Agrifood*" project launched in South Africa (Lan, Brewster, Spek, Smeenk, Top, 2017, p.112). The table grape safe consumption in South Africa was suitable for the project, as it involves information issues addressed by the blockchain. The table grapes travel long from a vineyard in the South African before they reach the plates of European consumers. Many consumers and retailers would like to know about table grapes if they can consume them. Are the grapes produced sustainably? In what kind of soil did they grow? What type of fertilizer was applied? What were the working conditions on the farm? Can we be sure of their safety and durability if we have a quality and authentic certificate? The answer to these questions is the Blockchain technology.

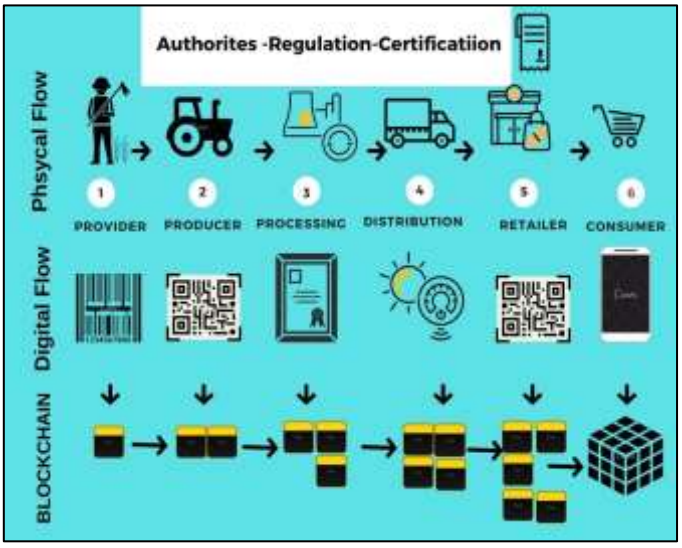
A compelling example is the experience of *Agri Digital* platform, founded in 2016. Since then, more than 1,300 users and more than 1.6 million tons of grain have been traded using the blockchain technology.

Louis Dreyfus Co, the world's largest food retailers, collaborated with Dutch banks for the first blockchain-based agricultural trade. The blockchain technology reduced five times the documents processing (Kamilaris, Fonts, Prenafeta-Boldύ, 2019, p.5).

Figure 2 presents an example of digitizing the food supply chain, based on blockchain technology.

The upper layer illustrates the physical flow, the stages and the participants of the agri-food chain. This chain system is ineffective and insecure; the exchange of goods is based on complex, non-transparent and complicated paper processes. In addition, the intermediaries' involvement raises the transaction costs (two-thirds of the final cost of agricultural products is the price of supply chains operating). The consumer is not conscious about the origin of obtained products or the ecological footprint of their production process.

Figure 2. Blockchain in Agriculture and Food Supply Chain



***Source**: Adopted by author after Kamilaris et al.,2019*

The digital flow level consists of several IT technologies (QR codes, digital signatures, sensors, *Near Field Communication (*NCF), *Radio-Frequency Identification* (RFID), computers and mobile phones) and the internet as an infrastructure.

All the digital technologies from the digital flow are recorded on the blockchain (the bottom layer). This level stores all the information a date accepted and validated by the parties involved in the supply chain. Once the blocks are validated, they are added to the whole transaction chain, becoming a permanent record of the entire process (Kamilaris et al., 2019).

At each stage of food trajectory (defined by numbers 1-6 in Figure 2), are different technologies involved, and various information is written on the blockchain, as described in table 1.

Between the most well-known projects and products based on blockchain technology, we can mention the projects promoted by:

1. *Oliva Coin* (Blockchain technology to support the small and medium enterprises in finance);
2. *Walmart, Kroger, IBM* (Blockchain for pork and mango traceability assurance)*;*
3. *Nestle (*Blockchain for pumpkin traceabilityin supply chain for kids' food*);*
4. *AgriLedger, FarmShare, Carrefour, OriginTrail, AgriBlockIoT* (Blockchain for financial traceability, food safety, supporting farmers, reducing waste, surveillance and management).

According to Kamilaris et al. (2019) the initiatives in blockchain technology for agriculture can be divided in four main categories:

1. Food security (Blockchain is regarded as an opportunity for the transparent delivery of international aid without intermediaries for veritable and accessible assets records and to respond efficiently to humanitarian emergencies).
2. Food safety (the processing conditions, hygienic storage and food manage are very important for illnesses prevention- blockchain helps to locate the history of the product, which is important for spoilable products).
3. Food integrity (secure exchange of the food in the supply chain, each participant should deliver total aspects about the origin of the goods).

Table 1. Phases of the agri-food supply chain and Blockchain technology

SUPPLY CHAIN PHASE	PHYSIC FLOW	DIGITAL FLOW (BLOCKCHAIN)
PRODUCER (FARMER)	*Production phase:* all implemented agricultural activities; raw and organic matter (fertilizers, seeds, animal breeds and feed). Throughout the year, depending on the crops and / or the animal production cycle, we may have one or more crops / yields.	Information about crops, pesticides and fertilizers used, machinery involved, etc. Transactions with the producer / farmer are recorded information about the farm and the agricultural practices used. Additional information on the process of growing crops, weather conditions or technologies for raising and feeding animals and their welfare.
PROCESSING	*The phase of total or partial transformation of a primary product into one or more by-products.* Subsequently, a packaging phase is expected, where each package could be uniquely identified by a production batch code containing information, such as the day of production and the list of raw materials used.	Information about the processing undertaking and its equipment, processing methods used, batch numbers, etc. Financial transactions that take place with producers and distributors.
DISTRIBUTION	*Distribution phase: packaged and labeled product.* Depending on the product, the delivery time can be set in a certain range. There may be a product storage stage at this stage.	Details about transport, routes followed, storage conditions (eg temperature, humidity), and transit time at each transport unit, etc. All transactions between distributors and final recipients are written on the blockchain.
RETAILER	Sales phase: at the end of distribution, the products are delivered to retailers who sell the product (retailers). The end user of the chain will be the customer, who will purchase the product.	Detailed information on each food product, current quality and quantity, expiry dates, storage conditions and shelf life are listed on the chain.
CONSUMER	*Consumption phase:* the consumer is the end user of the chain, buys the product and requests follow-up information on quality standards, country of origin, production methods, etc.	In the last step, the consumer can use a mobile phone connected to the Internet / Web or a web application to scan a QR code associated with a food product and see in detail all the information associated with the product, from the manufacturer and supplier to the unit.

Source: elaborated by author

4. Small farmers support (the creation of farmers 'cooperatives is an efficient way to increase the competitiveness of small farmers' households and their greater share of the crop market produced by them e.g. *OlivaCoin* for olive oil market).

Blockchain technology can be leveraged as a method for assessing the efficiency of surveillance and management of the food supply chain. It can be applied to improve the monitoring of international agreements relevant to agriculture, for example, World Trade Organization agreements. Blockchain-based contracts can also alleviate the exploitation of labor in agriculture, protecting workers with temporary contracts and labor relationships in the agricultural sector. When labor agreements become part of the blockchain, it is easier for authorities to control the correctness of payments and their taxation. Monitoring the quality of products (e.g. crops, meat, and dairy) along the food chain, storage conditions, contamination can be warranted by this technology.

Blockchain is a developing digital technology that will have a considerable impact on digital ecosystems by ensuring transparency and trust in food.

6.Conclusions

The research examined the meaning of blockchain technology on agriculture development and traceability of the agri-food supply chain. The well-proven experience of the analyzed in this research pilot-projects and achievements in the blockchain technology field emphasize its importance for agriculture digitalization and sustainable development.

International practice shows that the blockchain technology is already applied in many countries, to build a reliable and transparent ecosystem, and to ensure the sustainable development of production and distribution processes, blending all stakeholders (farmers, distributers, retailers, and consumers).

However, there are still some problems and challenges that need to be addressed beyond the technical ones. To benefit from new technologies,

governments need to promote the digitalization of public administration and spend more on education, research, innovation, and IT trainings for business.

The agri-food sector is currently facing major challenges all other the world. The digital ecosystem requires not only the usage of information and communication technologies (ICT) in all areas of activity, the electronic documents management and mutual settlements, the digital interaction of all subsystems and production processes, but also:

- Development of digital information and communication structures;
- Elaboration of new forms of electronic interaction;
- Information resources;
- Knowledgebase;
- Expanding the number of platforms for business, government and social integration;
- Digital environment;
- Staff able to work in cyberspace.

The national strategies and development policies should encourage the extension of blockchain ecosystems in agri-food chains, designing a transparent regulatory frame for the blockchain and innovative IT products.

Besides the advantages concerning the rights protection, taxes elimination, data protection and control, the blockchain technology offers a new vision on traditional management function even in agriculture that is a fruitful area for IT innovative technologies.

The blockchain technology is undoubtedly a promising one for the entire economy, with various initiatives for food security and agricultural chain supply management, but also with many obstacles and challenges, which limit its broader popularity between supply systems and farms. These challenges require technical issues, education programs, governmental policies and an appropriate regulatory framework.

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