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Comprehensive Assessment of the Effectiveness of the Implementation of Blockchain Solutions in Agribusiness Under the Condition of Systemic Risk

Abstract. Introduction*. The article provides a comprehensive assessment of the implementation of effective blockchain solutions in agribusiness in the face of systemic risks. These risks increase the uncertainty of agricultural companies' activities in the context of technological, institutional, economic, organizational, and cyber challenges.*

Purpose*. The study aims to categorize the risks associated with implementing blockchain technologies in agribusiness and develop a model for assessing the effectiveness of using blockchain solutions to mitigate external challenges in agricultural company operations.*

Results*. The study substantiates that using Blockchain in agribusiness increases supply chain transparency, product traceability, and reduces transaction costs and information asymmetry. It also strengthens trust between producers, financial institutions, and international partners. The study proves that the effectiveness of implementing blockchain solutions significantly depends on the level of systemic risk, formed by a set of restrictions under conditions of military instability and the transformation of the regulatory environment. A comparative analysis of Ukrainian agricultural companies' activities in the pre-war and war periods was conducted. This analysis revealed a consistent correlation between the intensity of their Blockchain solution implementation in the dynamic cycle of systemic risk and maintaining a stable income level and quality of corporate governance.*

Conclusions*. The study proposes a model for assessing the effectiveness of implementing blockchain solutions in agribusiness under the influence of systemic risk. This model is based on a combination of risk-oriented, network, and econometric approaches. The study defines an integral index of the effectiveness of implementing blockchain solutions in agribusiness in relation to systemic risk (EBC). Within the model, the quantitative characteristics of the coefficient of elasticity of blockchain solutions to systemic risk (IRs) are interpreted, which allows for an assessment of the effective sensitivity of digital innovation functions in the agricultural sector to changes in the regulatory environment. The study proves that agricultural companies with higher levels of corporate governance, financial stability, and developed Environmental, Social, and Governance (ESG) practices and access to external resources are characterized by lower elasticity of blockchain solutions to systemic risks. However, these companies have a high degree of investment support in the market.*

Keywords*: Blockchain; technology; agribusiness; systemic risks; efficiency; digital transformation; investment security; ESG transparency; international markets.*

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Комплексна оцінка ефективності впровадження блокчейн-рішень в агробізнесі за умови виникнення системного ризику

Анотація. *У статті проведено комплексну оцінку впровадження ефективних блокчейн-рішень в агробізнесі під впливом системних ризиків, які в умовах технологічних, інституційних, економічних, організаційних та кібернетичних викликів посилюють невизначеність діяльності аграрних компаній. Обґрунтовано, що використання блокчейну в агробізнесі сприяє підвищенню прозорості ланцюгів постачання, простежуванню агропродукції, зниженню транзакційних витрат і рівня інформаційної асиметрії, а також зміцненню довіри між виробниками, фінансовими установами та міжнародними партнерами.*

Доведено, що ефективність впровадження блокчейн-рішень істотно залежить від рівня системного ризику, який формується за комплексом обмежень в умовах воєнної нестабільності та трансформації регуляторного середовища. Проведено порівняльний аналіз результатів діяльності українських аграрних компаній у довоєнному та воєнному періоді, що дало змогу виявити стійку залежність між інтенсивністю впровадження блокчейн-рішень за умови виникнення динамічного циклу системного ризику та забезпечення стабільного рівня доходу й якості корпоративного управління.

Запропоновано модель оцінки ефективності впровадження блокчейн-рішень в агробізнесі під впливом системного ризику, що базується на поєднанні ризик-орієнтованого, мережевого та економетричного підходів. У межах дослідження визначено інтегральний індекс ефективності впровадження блокчейн-рішень в агробізнесі по

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відношенню до системного ризику (EBC). Інтерпретовано кількісні ознаки коефіцієнта еластичної дії блокчейн-рішень до системного ризику (IRs), що дозволило оцінити результативну чутливість функції цифрових інновацій в аграрному секторі при зміні факторів регуляторного середовища.

Доведено, що аграрні компанії з вищим рівнем корпоративного управління, фінансової стійкості та розвинутими ESG-практиками доступу до зовнішніх ресурсів характеризуються нижчою еластичністю дії блокчейн-рішень до системних ризиків, але водночас мають високий ступінь інтенсивності інвестиційного забезпечення на ринку.

***Ключові слова**: блокчейн; технології; агробізнес; системний ризик; ефективність; цифрова трансформація; інвестиційне забезпечення; ESG-прозорість; ринок.*

***JEL Classification:** Q16; O33; G32; L86; M21*

Formulation of the problem. Blockchain technologies are becoming an increasingly important tool for the digital transformation of agribusiness. They are capable of significantly changing the way production, logistics, and financial processes are organized in agri-food value chains. They provide decentralized, immutable, and transparent transaction accounting, which fosters trust among market participants, reduces information asymmetry, and minimizes transaction costs. In practice, blockchain solutions are increasingly used to verify the origin of agricultural products, control the quality and safety of food products, manage contracts and financial flows, and integrate with sustainable development and environmental, social, and governance (ESG) transparency systems.

In Ukrainian agribusiness, interest in blockchain is driven by the need to increase competitiveness in international markets and by external counterparties' requirements for transparency and traceability of agri-food products. Blockchain is seen as a tool for tracking certified products and managing data on acreage, resource use, logistics routes, warehousing, and certification procedures. This is particularly relevant for large agricultural companies operating in complex, multi-level supply chains and interacting with international financial institutions, traders, and regulators.

At the same time, implementing Blockchain technology in the agricultural sector is not an unambiguously positive process. It is accompanied by a significant number of risks. These risks include technological issues related to integrating blockchain with existing information systems and digital infrastructure, organizational and personnel issues caused by a lack of specialists and the need to transform business processes, financial issues arising from high initial implementation costs and the uncertainty of economic effects, and institutional and legal issues related to regulatory uncertainty, data protection, and the legal status of smart contracts. Together, these factors can significantly impact the economic efficiency of agricultural companies and hinder the widespread adoption of blockchain technologies in their businesses.

Given this, the need for a comprehensive risk analysis of introducing Blockchain to agribusiness and assessing its impact on agricultural companies' performance is urgent. Such an analysis would enable the development of a scientifically based risk management system for digital transformation, the identification of critical areas of blockchain influence on investment support and competitiveness of agricultural companies, and the establishment of a framework for the implementation of blockchain solutions.

Analysis of recent research and publications. In recent years, the scientific literature has increasingly focused on analyzing the application of blockchain technology in agri-food supply chains to ensure transaction transparency and increase business process efficiency. Research on this topic includes a general assessment of blockchain's potential and a detailed consideration of the practical barriers, risks, and factors that influence its implementation in agribusiness. One of the first domestic studies in this area was conducted by O. Hrybynyuk, B. Dukhnytskyi, and O. Sheremet. They revealed the economic essence of blockchain and its applied value for the agricultural sector, including the potential to increase transparency in agro-food chains, improve product traceability, and reduce transaction costs. However, they also emphasized limitations associated with the level of digital infrastructure and enterprises' readiness to implement innovations [2].

The systematicity of the empirical studies conducted by S. Roche, L. de Oliveira, and E. Talamini shows that the application of financial, logistical, and environmental aspects of Blockchain technology in agribusiness is in its initial stage of development. These studies also show that there is a lack of implication of digital inclusion with the economic efficiency and scalability of Blockchain solutions under the real conditions of agricultural company functioning [10]. Meanwhile, N. Miryala highlights the challenges of blockchain implementation in the agri-food sector with regard to cyber risks, scalability, and integration with existing digital platforms [9].

G. Akella, S. WiboWo, S. Grandhi, and S. Mubarak highlight the issues of barriers and factors of blockchain implementation in the context of sustainable agribusiness. They focus on the key technical, organizational, and institutional limitations of integrating IoT systems and cybersecurity in agriculture, as well as the high cost of innovative technologies associated with these processes and the lack of qualified personnel for the timely adoption of effective blockchain solutions [7].

Among Ukrainian scientists, N. Myrnyi's work is notable. He analyzes the possibilities of adapting blockchain to the conditions of the domestic agricultural sector by comparing it with traditional centralized IT systems. He also substantiates the potential benefits of

its use for large agricultural companies in managing contracts, logistics, and financial flows [4]. However, I. Blagun's study of the indirect impact of blockchain on agribusiness through logistics processes proves that the complexity of agri-food supply chains makes logistics one of the key areas of blockchain application, especially with regard to risk management and increasing transparency. This requires legal instruments for regulation [1]. V. Kachuriner considers the legal aspects of blockchain implementation in agro-industrial production and focuses on the legal status of smart contracts, data protection, and coordinating these issues with international regulatory requirements at the level of national legislation [3].

Thus, an analysis of recent research and publications shows that scientific discourse on Blockchain development in agribusiness focuses on transparency, traceability, data security, and digital integration. However, the issue of quantifying the effectiveness of blockchain solutions in agribusiness in the presence of systemic risks affecting investment attractiveness, environmental, social, and governance (ESG) positioning, and the readiness of agricultural companies to enter international markets remains underdeveloped. This highlights the need for further research in this area.

Formulation of research goals. The study aims to categorize the risks associated with implementing blockchain technologies in agribusiness and develop a model for evaluating the effectiveness of blockchain solutions in mitigating external challenges in agricultural company operations.

Presentation of the main research material. As a distributed ledger technology, blockchain provides a decentralized, immutable, and transparent record of data without the involvement of a trusted, centralized intermediary. This architecture guarantees the integrity and authenticity of transaction information, which is critical in complex agri-food value chains. Classically, blockchain consists of a chain of blocks, each containing a group of transactions protected by cryptographic methods. This makes it impossible to edit the transactions without authorization after they are approved by the network of participants. This data structuring principle ensures a high level of security and tracking of operational information, significantly increasing the transparency of business processes [4; 2].

Research shows that blockchain can perform several functions in the agricultural sector. These include confirming product origin, automating contractual obligations through smart contracts, increasing trust between supply chain participants, and reducing information asymmetry between producers and consumers. In other words, blockchain's integrity and reliability form the basis for transparent operational management mechanisms in agrarian businesses, serving as an "innovative platform based on smart contracts for e-commerce and management system automation, improving agrarian business efficiency and ensuring its sustainable development" [4].

In the field of agribusiness, Blockchain technology can be used, firstly, to ensure the tracking of the path of products (goods) from the field to the consumer, which allows to guarantee the quality, safety and origin of products [11]; secondly, for the automation of contractual relations, i.e., the use of smart contracts for the automatic fulfillment of contracts' terms between market participants [7]; thirdly, to optimize logistics processes by integrating IoT sensors and SCM (Supply Chain Management) systems to collect and save data in real time [6; 14]; and fourthly, to increase the transparency of financial flows to facilitate tracking payments and settlements and reduce the risk of financial transaction fraud [5].

The effectiveness of blockchain implementation in the agro-industrial sector depends on the presence and level of systemic risks.

It is advisable to classify the risks of using blockchain technologies in agribusiness according to several key groups: technological, institutional-legal, economic, organizational-management, and market (Fig. 1). This approach allows for a comprehensive assessment of the impact of blockchain solutions on the business processes of agricultural companies and helps determine the critical limitations of their effective application.

Technological risks are primarily related to the maturity level of blockchain platforms and their ability to adapt to the specifics of agribusiness. These risks include system scalability, limited network bandwidth, the energy consumption of individual consensus algorithms, and the vulnerability of smart contracts to software code errors. For agricultural companies that work with large amounts of operational data (e.g., logistics, certification, quality control, and product traceability), the low productivity of blockchain systems can result in delayed business processes and decreased operational efficiency. Additionally, integrating Blockchain with existing information systems (ERP, SCM, and IoT) fragments the digital infrastructure, creating risks of incompatibility with existing IT systems and increased costs. Under these conditions, the expected benefits of transaction automation, increased transparency, and reduced operational costs may be realized with significant delays or be offset by the additional costs of adapting the technology.

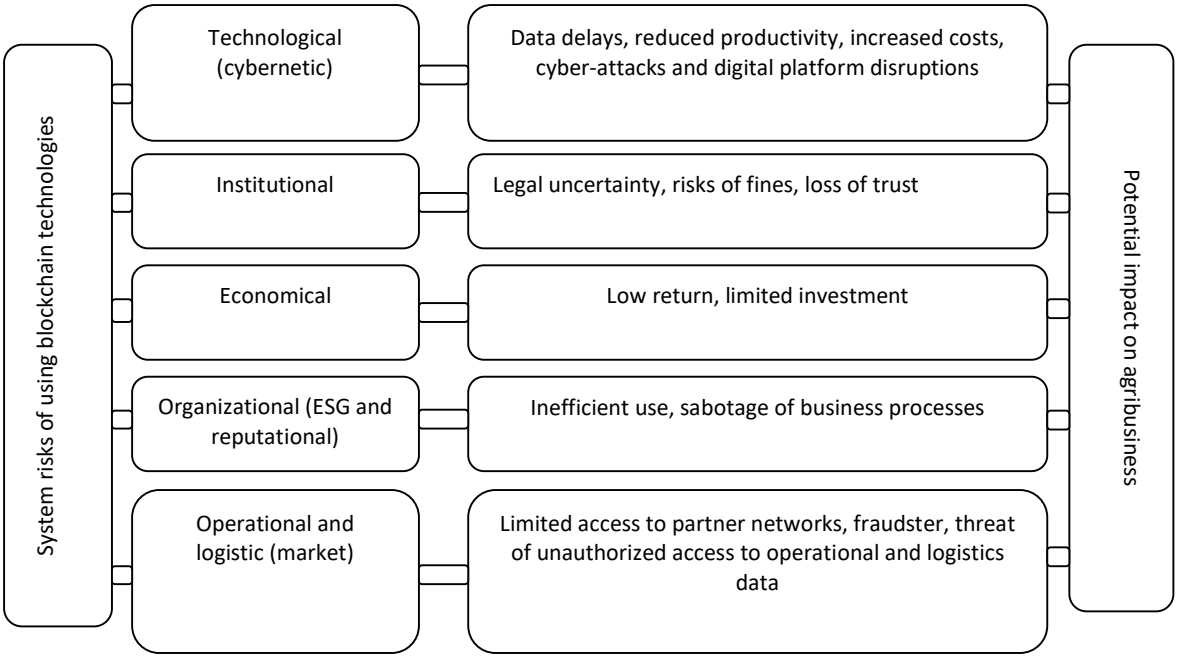

Figure 1 – **The potential impact of systemic risks on the effectiveness of Blockchain application in agribusiness**

Source: built by the author based on data [6; 12; 3]

Institutional risks are particularly significant for agribusinesses because agricultural activities are strictly regulated by national and international legislation. The legal status uncertainty of blockchain records, smart contracts, and digital assets can create additional legal risks for agricultural companies, especially when exporting products or raising financing. The lack of harmonized regulatory approaches to blockchain technologies makes scaling them difficult and reduces investor and financial institution confidence. Consequently, the potential benefits of blockchain, such as reduced transaction costs, may be offset by increased legal and compliance costs. Institutional risks significantly impact the effectiveness of blockchain in martial law and are exacerbated by frequent changes in regulatory requirements, the growing role of administrative decisions, and the increased dependence of agricultural businesses on institutional state support, reducing the predictability of economic outcomes of blockchain investments.

Economic risks are associated with the high initial cost of implementing blockchain technology and the uncertainty of its return on investment. Most agricultural enterprises, especially small and medium-sized ones, have limited financial resources, which makes them more sensitive to investment risks. Implementing blockchain requires costs for developing or acquiring software solutions, training personnel, cybersecurity, and technical support. Without a clearly measurable economic effect, such as an increase in selling prices, a reduction in losses, or access to new markets, the efficiency of using the technology may be lower than expected. Meanwhile, economic risks manifest as high exchange rate volatility, limited access to long-term capital, increased financing costs, and increased sensitivity to macroeconomic shocks. In such conditions, investments in blockchain technology are characterized by an increased level of uncertainty regarding payback periods and the scale of the economic effect. This directly affects the effectiveness indicators of digital solutions and restrains their widespread implementation.

Organizational risks arise from the necessity of transforming agricultural companies' business processes. Blockchain provides increased transparency and standardized data, which often conflicts with established management practices, particularly in integrated agricultural companies. Management and staff resistance to change, a shortage of digital competencies, and the absence of a clear digital development strategy can significantly reduce the effectiveness of implementing blockchain technologies. Under these conditions, blockchain is used in a fragmented manner, without creating a systemic effect for the entire value chain.

The effectiveness of blockchain solutions depends largely on the level of involvement of all supply chain participants, including manufacturers, traders, logistics companies, certification bodies, and financial institutions. A lack of readiness among partners to use digital platforms or uniform data exchange standards limits the network effect of blockchain technology. Additionally, consumers are often unwilling to pay a premium for products with proven blockchain tracking of business transactions, which reduces the technology's commercial impact. Therefore, in the context of the

global digital transformation of economic sectors – particularly the agricultural sector – operational and logistical risks are increasing due to an increase in cyberattacks, threats of unauthorized data access, and possible digital platform malfunctions regarding product (asset) logistics, which is especially important in military operations [13]. Despite the high level of security of the blockchain architecture, vulnerabilities can occur at the level of integration with external systems, use of interfaces, and management of access keys to operational and logistics business processes. This increases the risk of data loss and reputational damage for agricultural companies related to ESG criteria of market action transparency.

In our opinion, in today's conditions, agricultural companies need to focus management actions on key risks that hinder the scaling of blockchain technology and lead to irrational business processes in the market. These risks are technological, institutional, economic, and cyber.

We propose forming a single systemic risk factor that influences the effectiveness of implementing blockchain solutions in agribusiness. This factor is based on an aggregate of specified risks and is modified into an integral indicator. In our opinion, effectively implementing blockchain solutions in agribusiness depends heavily on systemic risk. The intensity of systemic risk increases significantly under conditions of military instability and deep regulatory environmental transformation. This can potentially reduce the positive effects of blockchain solutions on operational effectiveness, investment support, and environmental, social, and governance (ESG) transparency of agricultural companies' positions in the international market. Therefore, developing a comprehensive approach to evaluating the potential effectiveness of Blockchain in agribusiness and implementing an econometric model will allow us to create clear, step-by-step business cases for integrating Blockchain platforms with existing IT systems (IoT, Big Data) and establish a favorable regulatory environment that limits the impact of systemic risk on the implementation of Blockchain solutions in the agricultural sector. Only under these conditions can blockchain become more than just an innovative tool and become a real factor in increasing the efficiency and sustainability of agribusiness.

A comprehensive approach to assessing the effectiveness of blockchain implementation in agribusiness combines a quantitative assessment of operational efficiency according to technical and economic indicators, a qualitative, risk-oriented assessment of the value-added logistics chain, and an analysis of factors impacting the competitiveness of agricultural companies. This methodical approach considers not only the direct economic benefits of reduced transaction costs, but also the indirect effects, such as access to new markets, improved ESG indicators, and increased investment attractiveness of agricultural companies.

We propose an econometric model based on the quantitative assessment of risk and weighting factors for their overall impact on performance indicators, which measure the results of implementing blockchain solutions in agribusiness (Table 1).

Table 1 **A set of risk factors and performance indicators for measuring the result of implementing Blockchain solutions**

Risk category	Conditional value, (R_i)	Weighted risk factor, (W_i)	Effect category	Conditional value, (E_i)
Technological (cyber) risks (cyber risks, ERP-Blockchain integration)	R_1	0,25	Reduction of transaction costs, improvement of cyber protection of business processes	E_1
Institutional risks (regulatory uncertainty, legal status of smart contracts)	R_2	0,15	Increasing data transparency	E_2
Economic risks (currency risks, access to financing)	R_3	0,20	Reduction of time for processing operations	E_3
Organizational (ESG and reputational)	R_4	0,25	Reduction of compliance risks (fines)	E_4
Operational and logistical risks (war, ports, supply chain disruptions)	R_5	0,15	Access to financing of logistics chains of products (assets)	E_5

Source: developed by the author

The integral index of systemic risk and its impact on the effectiveness of implementation of Blockchain solutions is calculated according to formula (1):

$$IR_s = \sum_{i=1}^{n} R_i \times W_i , \quad (1)$$

where, IR_s – the integral index of systemic risk and its impact on the implementation of Blockchain solutions; R_i – risk category of the *i*-th type; W_i – weight factor for the *i*-th risk; n – the total number of risks affecting the implementation of Blockchain solutions.

Each risk has a standardized value and is calculated on a scale [0; 1], where 0 is no risk, 1 is the maximum risk, which significantly reduces the effectiveness of implementing Blockchain solutions. The interpretation of the integral index shows a range from 0 to 1, that is, if $IR_s \geq 0$, the greater the probability of a negative impact of a set of risk factors on the implementation of Blockchain solutions.

The integral index of the effectiveness of the implementation of Blockchain solutions by an agricultural company in the presence of the influence of systemic risk is calculated according to formula (2):

$$E_{adj} = E_{base} \times (1 - IR_s) , \quad (2)$$

where, E_{adj} – an integral index of the effectiveness of the implementation of Blockchain solutions by an agricultural company in the presence of the influence of systemic risk; $E_{base\,i}$ – a structural (potential) index of the effectiveness of the implementation of Blockchain solutions, which does not depend on risks.

The multicative model ($E_{base\,i}$) is determined by the internal characteristics of the agricultural company (depends on the scale, digital maturity, integration of business processes), the calculation of which is given by formula (3):

$$E_{base} = \lambda_1 \times S_{cale} + \lambda_2 \times Digital + \lambda_3 \times Integratio\ n , \quad (3)$$

where, S_{cale} – the business scale (land bank) in the range [0;1]; $Digital$ – level of digital maturity in the range [0;1]; $Integratio$ – integration of business processes (value creation chain) in the range [0;1]; $\lambda_1, \lambda_2, \lambda_3$ – weighting coefficients of business scale (land bank), digital maturity and integration processes, which have an impact on indicators within the value range of 0,4; 0,3 and 0,3, respectively.

Calculation of income from the activity of an agricultural company (REV) is calculated according to formula (4):

$$REV_t = S \times Y \times P_t , \quad (4)$$

where, REV_t – income from agricultural company activity, USD; S – land bank, thousand hectares; Y – 4,2 tons/ha (average marketable yield); p_t – average sale price (USD/ton, in constant prices).

It should be noted that the effectiveness of implementing Blockchain solutions in agribusiness depends on informational, economic and operational components, each of which has its own significant influence, namely 70%, 90% and 60%, respectively.

It should be noted that systemic risk significantly reduces the economic efficiency of blockchain solutions (EEB), which is critical for agricultural companies when forming a logistics chain of creating added value for products (assets), as well as for investors. Information efficiency (IEB) remains relatively high even during crisis years – a key advantage for ESG market transparency and product certification. Agricultural companies with a large land bank (>40 thousand hectares) benefit from the scaling effect of Blockchain solutions, even at high IR. For medium-sized companies (15,0-30,0 thousands hectares of land bank), pilot or industry Blockchain platforms are appropriate, rather than full individual integration. Within the framework of the econometric model, it is necessary to determine the interpretation of quantitative signs of the coefficient of elastic action of Blockchain solutions (EBC) to institutional risk (IRs), which will allow evaluating the effective sensitivity of the function of digital innovations in the agricultural sector when the factors of the regulatory environment change.

The econometric model based on a complex approach allows estimating the coefficient of elasticity of Blockchain solutions in agribusiness to systemic risk, the interpretation of which involves a multiplicative log-linear function, represented by formula (5).

$$In(E_{adj\,it}) = \alpha + \beta In(1 - IR_{it}) + \varepsilon_{it} , \quad (5)$$

At the same time, the elasticity of Blockchain solutions to systemic risk ($\varepsilon_{E_{adj},IR}$) is determined by formula (6).

$$\varepsilon_{E_{adj},IR} = \frac{\partial E_{adj}}{\partial IR} \times \frac{IR}{E_{adj}} , \quad (6)$$

By substituting formula (2) into the algorithm for calculating the indicator ($\varepsilon_{E_{adj},IR}$) we obtain a modified version of the indicator (formula (7):

$$\varepsilon_{EBC,IR} = E_{base} \times \frac{IR}{1 - IR} , \quad (7)$$

The conducted empirical analysis of the effective activity of 27 agricultural companies located in the Western, Central, Eastern and Southern regions of Ukraine, based on averaged data for 2021-1st half of 2025, demonstrates the presence of a systemic risk of influence on the implementation of Blockchain solutions, which partially limits the functionality of enterprises on

the market due to military actions on the territory of the country (Table 2).

Table 2 **Profitability, profitability and effectiveness of implementation of Blockchain solutions by agricultural companies of Ukraine to ensure the logistics chain of added value on the market on average for 2021-I half of 2025**

Company	Land bank, thousand ha	Average income, million USA	Average profit, million USA	IEB	EEB	OEB
VOLYNJ-AGRO	6	6,2	0,9	0,64	0,55	0,69
AGROTECHSERVIS-C	1	1,0	0,15	0,64	0,55	0,69
Dokuchaev chernozems	12	12,4	1,8	0,64	0,55	0,69
Aurum Group	12	12,4	1,8	0,64	0,55	0,69
Stepova	13	13,4	2,0	0,64	0,55	0,69
Zaporizhzhia-Agro	14	14,4	2,1	0,64	0,55	0,69
APGC Dniprovsk	15	15,5	2,3	0,64	0,55	0,69
Agrodar groups	15	15,5	2,3	0,64	0,55	0,69
Agro-Aries	16	16,5	2,4	0,64	0,55	0,69
Pyatikhatska	17	17,6	2,6	0,64	0,55	0,69
Consent	17	17,6	2,6	0,64	0,55	0,69
Preobrazhenske	18	18,6	2,8	0,64	0,55	0,69
Zoria	20	20,7	3,0	0,64	0,55	0,69
Ahroinvest Kholdynh	22	22,8	3,4	0,64	0,55	0,69
KSG Agro	24	24,8	3,7	0,64	0,55	0,69
Rozkishna	24	24,8	3,7	0,64	0,55	0,69
VPK-Ahro	27	27,9	4,2	0,64	0,55	0,69
AgroGeneration	31	32,0	4,8	0,64	0,55	0,69
Dnipro Agro Group	33	34,1	5,1	0,64	0,55	0,69
LANDFORT	41	42,4	6,4	0,64	0,55	0,69
Ahrospetsservis	50	51,7	7,8	0,64	0,55	0,69
Chysta krynytsia	50	51,7	7,8	0,64	0,55	0,69
Farm Forvard	54	55,9	8,4	0,64	0,55	0,69
Ristone Holdings	66	68,3	10,2	0,64	0,55	0,69
AhroVista	75	77,6	11,6	0,64	0,55	0,69

Source: calculated by the author

The obtained calculations according to the data in the Table 6, allow us to note the existence of a relationship between the scaling effect of Blockchain solutions in the agribusiness of Ukraine and the level of systemic risk in order to ensure the logistics chain of added value on the market in 2021-I half of 2025.

First, a clear direct relationship between the size of the land bank and absolute financial results has been established. Companies with a land bank of more than 40.0 thousands hectares (LANDFORT, AGROTECHSERVIS-C, Farm Forvard, Ristone Holdings, AhroVista) demonstrate significantly higher average revenues and profits, which forms a broader financial base for investing in digital infrastructure, including Blockchain solutions. This creates economies of scale, whereby the fixed costs of technology implementation are spread over a larger volume of operations, increasing the overall economic feasibility of digitization.

Second, the results confirm that systemic risk has an asymmetric impact on the effectiveness of various blockchain technologies. Economic Efficiency (EEB) was found to be the most sensitive, with an average value lower than that of informational and operational efficiency. In other words, when faced with war-related instability, currency fluctuations, and regulatory uncertainty, investors and lenders tend to discount the potential financial benefits of Blockchain solutions, even if they are technologically feasible.

Third, Information Efficiency (IEB) remains relatively stable for all groups of firms, regardless of their land bank size. This demonstrates that blockchain solutions offer lasting advantages in transparency, traceability, and data quality, even in the face of significant systemic risks. This property makes blockchain a critical tool for confirming product origin, transparency, and meeting ESG requirements.

Fourth, Operating Efficiency (OEB) exhibits moderate risk sensitivity and increases with company size. Large agricultural enterprises can integrate blockchain technology into their logistics, warehousing, and contract processes, while small and medium-sized companies mainly benefit at individual stages of the value chain. This confirms the usefulness of modular or platform implementation of blockchain solutions for medium-sized agricultural enterprises.

Fifth, the comparison of Blockchain performance indicators and indices shows that the economic effect of digitization is enhanced in agricultural companies with

higher profitability, as they are able to compensate for risks due to diversification of activities, better access to capital and more developed corporate governance systems. In small agricultural companies, the implementation of Blockchain without external support (cooperation, state or donor programs) may not provide sufficient economic effect.

Conclusions. The research revealed that a comprehensive assessment of the effectiveness of implementing blockchain solutions in agribusiness must consider direct economic benefits and systemic risks that could hinder large-scale adoption of the technology. Successful digital transformation requires the creation of a favorable institutional environment, development of IT infrastructure, personnel training, and legal support for implementing the latest solutions.

Calculations prove that blockchain technologies are more of a mechanism for reducing non-financial risks, increasing counterparty trust, and improving the investment image of agricultural companies than a tool for direct profit growth. This is especially important when expanding into new markets, increasing the added-value logistics chain of products (assets), attracting international financing, and establishing an ESG positioning.

In summary, the effectiveness of using blockchain technologies in Ukrainian agricultural companies (agroholdings) depends on the business's scale, the level of systemic risk, and its strategic goals. In conditions of high volatility, it is advisable to consider blockchain as an element of long-term digital and institutional stability rather than just a tool for improving economic indicators in the short term.

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