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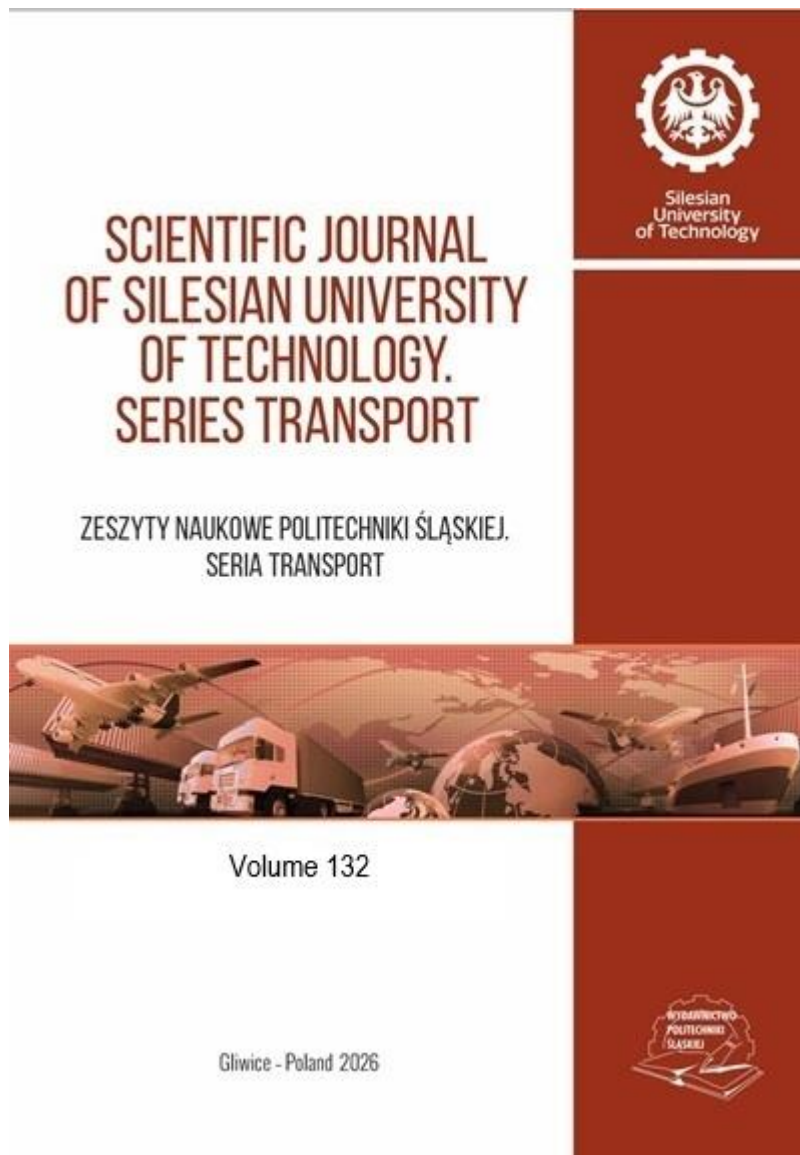


Fig. 1. Cover of issue vol. 132 / 2026

volume 132

1. [Mustafa ALBDAIRI, Ali ALMUSAWI: Traffic instability thresholds at freeway off-ramps under mixed autonomous-human vehicle flows: role of AV behavioral profiles.PDFXMLHTML](#)
2. [Veysi ASKER: Measuring operational and revenue productivity at airports before and after the Covid-19 pandemic: application at selected airports in Turkey.PDFXMLHTML](#)
3. [Alena BREZNICKÁ, Pavol MIKUŠ, Michal KRBAŤA, Marcel KOHUTAR, Ľudmila TIMÁROVÁ, Jozef Jaroslav FEKIAČ, Lucia KAKOŠOVÁ, Alex JELUŠ: Analytical and simulation approach to estimating the failure probability of technical components using an interference model.PDFXMLHTML](#)
4. [Marek BUGDOL, Józef OBER, Charli SITINJAK: Model of attitudes towards free public transport.PDFXMLHTML](#)

5. [Michal DRÁBEK, Jiří POSPÍŠIL, Roman ŠTĚRBA, Milan KŘÍŽ, Rudolf Franz HEIDU: Tailor-made train path homogenization – a capacity improvement for mixed rail traffic.PDFXMLHTML](#)
6. [Alina FEDORCHUK, Artur GOŚ: Comparative analysis of radar systems in regional aviation: a case study of Deblin airfield.PDFXMLHTML](#)
7. [Quang Tuan HOANG, Hai Quan VU: Parametric study on the magnetic circuit of MR mounts utilizing magnetic shielding.PDFXMLHTML](#)
8. [Alexander ILKSTRÖM KRAVCOV, Jan KOTISA, Martin VLKOVSKÝ, Romana HEINZOVA, Holger BACKHAUS: Comparative transport capability of T-72 and Leopard 2 main battle tanks in Central Europe: implications for military mobility.PDFXMLHTML](#)
9. [Aleksander JAGIEŁŁO, Agnieszka SZMELTER-JAROSZ, Marcin WOŁEK: Monitoring the energy transition of bus public transport companies: a process-oriented approach.PDFXMLHTML](#)
10. [Ha KHUONG THI, Van NGUYEN CAO: Artificial neural network-based prediction of in-cylinder pressure and pressure rise rate in a PCCI diesel engine.PDFXMLHTML](#)
11. [Kamil KRASUSKI, Mieczysław BAKUŁA, Piotr MIDUCH: Accuracy analysis of vehicle positioning using GPS and GLONASS data.PDFXMLHTML](#)
12. [Michał LASOTA, Marianna JACYNA: Application of the FMEA method to support risk assessment in the organization of road transport of oversize loads.PDFXMLHTML](#)
13. [Anh Ngoc NGUYEN, Xuan Hien NGUYEN, Tuan Quang PHAM, Hai Quan VU: Enhancing ride comfort for the driver and passengers in a five-seat vehicle using regression modeling, TOPSIS, and PID control.PDFXMLHTML](#)
14. [Artem PAVLYCHENKO, Oleg LYASHUK, Vitaliy KRIVDA, Olha SAKNO, Dmytro MIRONOV, Kostyantyn KORNILENKO, Roman KHOROSHUN: Impact of changes in the technical-operational performance of hybrid vehicles as a partially decarbonized technology on end-of-life treatment with regard to environmental requirements.PDFXMLHTML](#)
15. [Muhammad REZA, Wawan PURWANTO, Toto SUGIARTO, Budi UTOMO: Effect of the number of injector holes and gasoline ethanol blended on fuel consumption, AFR, and engine performance.PDFXMLHTML](#)

16. [Inna RIEPINA, Oleksandr SADOVNYK, Sergii IVASHCHENKO, Vitalii NITSENKO, Mariia TEPLIUK, Tamara LOZYNSKA, Volodymyr TSIUPAK: Modern challenges and opportunities for the development of agrarian trade logistics in Ukraine in the context of anti-entropy.PDFXMLHTML](#)



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**MODERN CHALLENGES AND OPPORTUNITIES FOR
THE DEVELOPMENT OF AGRARIAN TRADE LOGISTICS IN
UKRAINE IN THE CONTEXT OF ANTI-ENTROPY**

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Summary. The article is devoted to the analysis of current problems, trends and opportunities for the grain trade market development in Ukraine in the context of ensuring anti-entropy. In recent years, Ukraine has established itself as one of the world's leading exporters of grain crops, such as wheat, corn and barley. The significant contribution of the agricultural sector to the country's economy emphasizes the importance of a detailed study of the factors affecting its development, which is extremely important for ensuring the competitiveness of our country in the geopolitical arena. The key challenges for grain trade remain infrastructure limitations. The problem of logistical leverage, including the insufficient development of ports, railway and road infrastructure and other obstacles. At the same time, the article emphasizes that climate change also poses a serious threat, causing instability of yields and increasing production costs; in particular, weather conditions are extremely unstable and difficult to predict. Also, an important aspect is that logistical problems, such as delays in transportation and storage of grain, limit the ability of Ukrainian exporters to compete in the market globalization. Let's next step, these characteristics are complemented by geopolitical events that affect trade routes and export markets, creating additional instability. The article analyzes the dynamics of exports of major grain crops in the 2023/2024 marketing year. The article carefully examines the impact of world prices and trade conditions on the agricultural sector's economic efficiency. Changes in global markets and product quality requirements require Ukrainian producers to adapt and implement the latest technologies to ensure competitiveness. Particular attention is paid to strategies aimed at increasing the efficiency of grain trade. Among the proposed areas are improving the infrastructure for storing and transporting grain, diversifying production to reduce risks associated with climate change and price fluctuations in international markets. An important aspect is the introduction of innovative technologies in grain production and processing, which will contribute to increasing the productivity and sustainability of the sector. Also, the issue of adaptation to global market changes is considered, where the demand for environmentally friendly products is growing, which is a problematic aspect for modern ecological conditions. In this context, the need to implement sustainable development practices is emphasized, including reducing greenhouse gas emissions and rational use of resources. Increasing the sustainability of the grain market through the creation of more flexible logistics systems and risk management mechanisms is key to ensuring long-term economic efficiency. In conclusion, the article offers strategic recommendations for the government and business on the grain trade market development in Ukraine. Given the importance of this sector for the country's economy, special emphasis is placed on the need for intersectoral cooperation, investment in scientific research, and infrastructure development, which will ensure the agricultural sector's sustainable development and its integration into the global arena.

Keywords: grain trading, logistics, agribusiness, entropy, competitiveness, sustainable development, diversification, infrastructure development, supply chain resilience, trade strategies, market adaptation

1. INTRODUCTION

Today, under the influence of entropic shocks and adverse global trends such as military conflicts, quarantine restrictions, and financial and economic crises, Ukraine continues to maintain leading positions in the global grain market (Shlapak et al., 2023). This status highlights the critical importance of grain trade as a key driver of economic growth, strengthening the country's role in the global arena and ensuring its competitiveness (Iatsenko et al., 2024). The current stage of the agricultural development sector is characterized by significant turbulence caused by both external factors, which necessitates the implementation of anti-entropic measures. In the era of globalization, digitalization, and intensified competition, Ukrainian grain traders face new challenges and opportunities that require adaptation to rapidly changing market conditions while simultaneously shaping a new vision for the further development of their business (Osadchuk et al., 2024).

The relevance of this topic is determined by the need to study current trends that shape the trajectory of grain trade development in Ukraine. These trends include the introduction of innovative technologies, improvement of logistics processes, development of export potential, and resilience to climate change (Petkevičiūtė–Stručko and Yauhen, 2018). In addition, modern methods of genetic engineering and advanced management practices play a crucial role. Equally important is the analysis of risks and threats associated with geopolitical factors, economic instability, and changes in global market dynamics, which emphasizes the significance of anti-entropic measures for agricultural development market. A comprehensive analysis of key trends, risks, and opportunities allows for a deeper understanding of the specific features of Ukraine's grain market and enables the formulation of recommendations aimed at enhancing its competitiveness. This, in turn, will contribute to ensuring stable economic development of the country and its integration into international agricultural markets.

Grain trade remains one of the key sectors of Ukraine's economy, playing a significant role in both domestic and international markets. Grain exports serve as the main driver of agribusiness growth, contributing to economic efficiency and competitiveness, which are vital for maintaining the country's economy at a sustainable level.

Under current conditions, the importance of logistics and risk management in grain trade is increasing due to changes in global supply chains, political influence, speculative practices, rising quality requirements, and the need for market flexibility and resilience. In this context, entropy is considered as a measure of uncertainty and chaos in the functioning of the agricultural market system. The manifestation of entropy results in the emergence of crisis phenomena or market destabilization, which negatively affect global food security. At the same time, some entropic factors may be natural in origin, while others are artificially created. This, in turn, influences the choice of an anti-entropic model for reducing relevant risks and the decision-making system at both the state and enterprise levels. Therefore, the concept of anti-entropic measures in grain trade involves the creation of systems capable of adaptation and sustainable development despite external challenges. Export diversification and innovative approaches to agribusiness management help reduce risks and strengthen market stability. The introduction of advanced technologies in production and logistics, a focus on environmental aspects, and sustainable development management models open new opportunities in the international arena for Ukraine.

2. LITERATURE REVIEW

In modern scientific literature, research in the agricultural sector occupies a priority position due to the need to increase the efficiency of agricultural production and ensure food security. For example, Atamanyuk et al. (2023) developed a mathematical model for forecasting winter wheat yields based on field experiments, significantly improving forecast accuracy. This study represents a valuable contribution to agricultural business management processes and aligns with the objectives of the present research. Andriushchenko et al. (2019) analyzed the prerequisites for creating financial and credit infrastructure to support agricultural enterprises in Ukraine, emphasizing the importance of financial mechanisms for sustainable agricultural development, particularly for small and medium-sized enterprises. Bazaluk et al. (2022) investigated grain cleaning systems using energy-efficient technologies, highlighting their potential to reduce energy costs and enhance production sustainability, thereby aligning with the principles of circular economy and sustainable development.

Sellitto et al. (2025) consider that the growing complexity of supply chains requires new analytical approaches, particularly the application of entropy-based methods for assessing the stability and adaptability of logistics systems. At the same time, Ilchenko (2025) focuses on the transport modernization and logistics infrastructure and proposes eco-adaptive approaches aimed at improving the efficiency of logistics networks. In contrast, Kulakova et al. (2023) analyze the formation of logistics costs under contemporary conditions and emphasize the increasing importance of flexible logistics strategies. Burg (2023) examines entropy as a concept originating from physics and demonstrates how it can be applied to evaluate efficiency within logistics systems. Rudik et al. (2022) investigate the adaptation of agricultural production systems to global challenges. Qin et al. (2022) analyze the potential geographical distribution of oats under climate change conditions and identify prospects for expanding its cultivation. Meanwhile, Sumets et al. (2022) propose a methodological toolkit for assessing the stability of agricultural enterprises, whereas Denysiuk et al. (2022) emphasize the role of diversification in ensuring the sustainable development of agribusiness entities. Tanklevska et al. (2020) study dynamic models of asset management in agricultural companies and highlight the importance of effective financial management for maintaining enterprise stability. Plakantara and Karakitsiou (2025) examine the transformation of agri-food supply chains through the implementation of digital technologies, emphasizing their role in improving safety and quality risk management. Sonar et al. (2025) analyze the integration of Industry 4.0 technologies into agri-food supply chains as a tool for increasing resilience and operational efficiency. Medvediev et al. (2024) develop a fuzzy logic model for risk management in agricultural supply chains based on the example of grain transportation routes between Ukraine and Poland. Xue et al. (2025) provide a comprehensive review of risks in agri-food supply chains and highlight economic vulnerabilities affecting global agricultural logistics. Kotenko et al. (2021) study the impact of economic crises on multimodal transportation routes, demonstrating how disruptions may transform logistics structures. Durowoju et al. (2012) apply entropy-based approaches to assess disruptions in supply chains and emphasize their usefulness in analyzing system instability.

Burkovska et al. (2021) stress the importance of integrating environmental and social aspects into agricultural development to ensure sustainability, particularly in response to the growing demand for environmentally friendly products. It is worth noting that Mirzoieva and Tomashevskiy (2023) explore the possibilities of developing niche grain production in Ukraine and highlight the economic potential of such crops. Dibrova and Stepasiuk (2023) analyze the economic attractiveness of oats as a promising niche crop for agricultural enterprises.

Holopainen-Mantila et al. (2023) examine oats as a cereal crop and describe its technological and nutritional properties. Klein (2022) considers initiatives aimed at stimulating oat cultivation through strengthening cooperation between farmers and food companies. Shubravskaya and Prokopenko (2022) analyze food security issues in Ukraine in the post-war context and emphasize the strategic importance of agricultural production. Petrunenko et al. (2021) study mechanisms for ensuring food security within the framework of sustainable development. Karimzada (2020) investigates broader aspects of food security in the context of global economic development. Pawlak and Kołodziejczak (2020) examine the role of agriculture in ensuring food security in developing countries. Kim (2016) highlights global opportunities related to alternative specialty crops, while Decker et al. (2014) analyze the processing and nutritional value of oat products. Earlier, Otsuka (2013) explored the relationship between agricultural development, income inequality, and food security in the global economy.

The influence of entropy on socio-economic and institutional systems is also widely discussed in the literature. Ostrovska et al. (2025) investigate the formation of technological ecosystems in the context of digital transformation. Riepina et al. (2022) analyze factors related to transport entrepreneurship that influence economic development. Mykhailichenko et al. (2021) study competitive strategies in personnel management within agricultural enterprises undergoing digital transformation. Ovcharenko et al. (2022) explore spatial organization management and the functioning of eco-clusters in the context of globalization.

Issues of entropy and managerial decision-making are examined in a number of studies. Ovdiiuk (2025) analyzes organizational and economic mechanisms of managerial decision-making at food industry enterprises. Materynska et al. (2025) investigate the principles and tools of sustainable development management. Andreichenko and Zhurylo (2025) focus on decision-making processes in agribusiness management. Sharko et al. (2024) propose an entropy model for determining the necessary information in the diagnostics of maritime transportation. Gonzalez-Bueno et al. (2024) analyze portfolio optimization models balancing risk, return, and liquidity. Kyryliuk and Liutyi (2023) examine management features in Ukrainian agricultural businesses, while Hutorov et al. (2018) analyze strategic management of the agrarian sector based on value chain analysis.

Entropy and turbulence in economic and production systems are further explored in the works of Zhao et al. (2014), who analyze entropy in turbulence modeling. Su et al. (2023) investigate entropy in complex physical processes using simulation methods. Oishi et al. (2023) assess the resilience of entropy-regularized logistics networks. Yu et al. (2025) study the application of entropy to reduce congestion in logistics systems. Bilokon (2025) considers entropy as a challenge to institutional sustainability in public administration under hybrid threats.

In general, the analysis of trends, risks, and opportunities in Ukraine's grain trade attracts considerable attention from researchers. Liu et al. (2023) investigate the cascading effects of grain trade shocks in the context of the Russia–Ukraine conflict. Korol (2025) analyzes the functioning of the Ukrainian grain market under wartime conditions. Panfilova et al. (2025) examine global trends in grain and seed trade and assess Ukraine's position in international markets. Belkin et al. (2025) study sustainable marketing strategies of Ukrainian agricultural enterprises entering global grain markets. Vlasov (2025) explores management accounting approaches supporting the marketing activities of agricultural enterprises.

Overall, these studies demonstrate that the integration of advanced technologies, effective risk management, and modern logistics infrastructure are key factors in ensuring the competitiveness and resilience of the Ukrainian grain market within the global economic environment. Based on a review of modern scientific literature, the state of the grain market in

Ukraine is characterized as a leading link among global producers and exporters of grain crops. Key players in the Ukrainian grain market include large agricultural holdings, as well as numerous small and medium-sized farms and state-owned enterprises, which can be reasonably integrated into an agro-ecosystem. Fertile soils and favorable climatic conditions in Ukraine have resulted in significant production of grain crops, particularly wheat, corn, and barley. At the same time, it should be noted that in recent years Ukraine has achieved a substantial increase in grain exports to international markets, further strengthening its position in global grain trade.

A thorough analysis of scientific sources indicates that the development of Ukraine's grain market is influenced by a range of factors, from state policy to international trade agreements, climate change, and environmental conditions. Undoubtedly, state policy plays a key role in supporting positive dynamics in agribusiness development, including subsidies, tariffs, and the regulatory framework. International trade agreements, such as the European Union Association Agreement, have opened new opportunities for Ukrainian grain exporters in foreign markets. At the same time, climate change remains a significant natural source of entropy for the agricultural market, affecting yields and the structure of agricultural production, which is further exacerbated by environmental changes.

The purpose of this study is to examine modern challenges and opportunities for the development of agricultural trading in Ukraine using the grain market as an example, as grain crops constitute the foundation for the development of Ukrainian agricultural producers operating under conditions of entropy and turbulence.

The object of the study is the existing grain trading system of Ukraine, which reflects economic relations among participants in global trading and functions under conditions of high entropy of the external environment.

3. MATERIALS AND METHODS

The study of agritrading logistics systems in Ukraine is a key task for ensuring the competitiveness of agricultural enterprises under conditions of entropy. The research involves a detailed analysis of the existing agritrading system and the efficiency of economic activities of producers of this type of products. The main objective of such studies is to develop models that make it possible to assess the relationship between key factors and the volume of product sales.

The methodological basis for constructing these models relies on economic and mathematical approaches, in particular correlation and regression analysis, which enables the identification of cause-and-effect relationships between the main parameters of enterprise performance. A key prerequisite for building such models is the use of valid datasets. Data generated on the basis of official statistical observations ensure the representativeness and reliability of the obtained results. Data validation helps to avoid methodological errors and increases the accuracy of economic and mathematical calculations. This, in turn, contributes to improving the effectiveness of managerial decision-making in agrologistics, cost optimization, risk reduction, and the achievement of strategic objectives of agricultural enterprises. Such an approach serves as an important tool for analyzing and forecasting the agritrading development logistics systems in Ukraine. The conducted scientific research belongs to a mixed-methods type, as it combines theoretical and empirical approaches in order to comprehensively examine the object of study and meets all relevant criteria: it integrates conceptual analysis with empirical verification and ensures a logical connection between theory and practice. The stages of the research include theoretical substantiation of the problem and hypothesis formulation,

development of data collection methodology, empirical analysis and hypothesis testing, and interpretation of results within the selected theoretical framework. The implementation of these stages makes it possible to provide a comprehensive explanation of the studied phenomenon, formulate practical recommendations supported by theory and data, and increase the level of scientific validity of the conclusions.

To form valid datasets for the analysis of agrolistics and grain trading in Ukraine, data from the State Statistics Service of Ukraine were used. Its official website provides access to official statistical information, descriptive analytical bulletins, and multisectoral datasets. A significant statistical data array on agribusiness logistics and trading was obtained from the official website of the Ministry of Economy, Environment, and Agriculture of Ukraine, in particular aggregated data from customs declarations related to cross-border movements of agricultural products of Ukrainian origin.

For qualitative grouping of information by types of agribusiness products, the Ukrainian Classification of Goods for Foreign Economic Activity (UCGFEA) was applied, which enabled detailed product identification and enhanced the analytical accuracy of the study. To form data arrays for correlation and regression analysis, information from the UN Comtrade database was used. This resource is based on United Nations merchandise trade statistics and aggregates global annual and monthly trade data by products and trading partners for governments, researchers, and businesses. The database covers over 200 countries and more than 99% of global trade; data are available in various formats, and users are provided with additional analytical and data-processing functionalities. The analytical period of the study covers January 2022 to December 2025.

To achieve the research objectives, quantitative data processing methods were applied, including data visualization (construction of charts, histograms, and tables for illustrative data presentation), factor analysis (to identify latent factors), and statistical analysis (statistical grouping methods, calculation of mean values, determination of correlation coefficients, and regression analysis).

Special attention was given to the mathematical framework of simple linear regression, which made it possible to model the relationship between two variables (Y – the variable to be predicted (dependent or output variable), X – the variable used to predict Y (independent variable, predictor, or input variable)). The mathematical form of a simple bivariate linear regression is expressed as:

$$y_1 = \beta_0 + \beta_1 x_i + \varepsilon_i \quad (1)$$

where β_0 and β_1 – are constants (model parameters) to be determined;
 ε_i (u_i) – model error.

To determine the model parameters, the least squares method (LSM) is used, which allows you to select such model parameters for which the residual sum of squares (RSS) from the real values will be minimal:

$$RSS = \sum_{i=1}^n (Y_i - \hat{Y}_i)^2 = \sum_{i=1}^n (Y_i - \hat{\beta}_0 - \hat{\beta}_1 X_i)^2 \quad (2)$$

The model parameters were calculated using the formulas:

$$\hat{b}_1 = \frac{\sum_{i=1}^n (Y_i - \bar{Y})(X_i - \bar{X})}{\sum_{i=1}^n (X_i - \bar{X})^2} \quad (3)$$

$$\hat{b}_1 = \frac{Cov(x, y)}{Var(x)} \quad (4)$$

$$\hat{b}_0 = \bar{Y} - \hat{b}_1 \bar{X} \quad (5)$$

In doing so, the necessary requirements for the interpretation of the coefficients of the OLS model were taken into account, in particular normality, independence, linearity and homoscedasticity.

The determination coefficient was taken into account, which measures the proportion of variation in the data in the model and indicates how much the model values coincide with the real ones. The coefficient is calculated by the formula:

$$R^2 = 1 - \frac{\sum_{i=1}^n (y_i - \hat{y}_i)^2}{\sum_{i=1}^n (y_i - \bar{y})^2} = 1 - \frac{Var(\hat{u})}{Var(y)} = \frac{Var(\hat{y})}{Var(y)} \quad (6)$$

To assess the relationship between two variables, the correlation coefficient was used, which is calculated as:

$$r = \frac{\sum (x_t - \bar{x})(y_t - \bar{y})}{\sqrt{\sum (x_t - \bar{x})^2} \sqrt{\sum (y_t - \bar{y})^2}} \quad (7)$$

The statistical significance of the model parameters was assessed according to the t-test (Student's test), which allows testing the hypothesis that the model parameter is equal to "zero". The larger the t-test value (and the lower the p-value), the more significant the predictor. The critical value of the t-test was determined from the corresponding Student distribution tables, where the column is defined as the confidence probability (α), and the row as the degree of freedom (n-m). The critical p-value was taken into account at the level of 0.05.

Research hypothesis: do the average selling price of agricultural products export affect the volume of sales, the country's place in providing world demand, the presence of intermediary countries and the period of the marketing year. The hypothesis is investigated using the example of the world wheat market and should identify current challenges and opportunities for the development of grain trading in Ukraine.

We consider that expanding Ukraine's export opportunities requires strengthening trade diplomacy, infrastructure development, and product range diversification, including niche crops. Ukraine should also work on introducing environmentally friendly production methods that meet international standards of sustainable development, which will allow domestic producers to maintain competitive positions in the agricultural market. An integrated approach

to overcoming challenges will ensure long-term stability and competitiveness of the Ukrainian grain market in the international arena. Therefore, in our opinion, effective consideration of these factors will allow Ukraine to overcome challenges and take advantage of growth opportunities in the global grain market. Despite significant advantages, the Ukrainian grain market faces a number of challenges that prevent it from fully realizing its potential. The main obstacles are market infrastructure limitations, in particular insufficient storage and transportation capacities. These problems complicate logistical operations for grain producers and exporters, and the full-scale invasion of the Russian Federation has further exacerbated the negative impact of these challenges. For example, in the 2023/24 marketing year, Ukraine exported more than 56 million tons of grains (wheat, barley, corn), legumes (soybeans) and oilseeds (sunflower, rapeseed) to more than 58 countries around the world. The main importers of Ukrainian grain were Spain, Egypt, China, Turkey, and Italy. However, in recent years, the situation regarding export channels has changed and there have been dramatic changes among the main exporting countries. As of 2025, the main exporting countries of grains and oilseeds were Egypt, Turkey, Spain, Italy and Algeria (Table 1).

Tab. 1

Top 30 exporting countries of Ukrainian grains, legumes and oilseeds in the 2025,
thousand tons

No	Country	Together	Wheat 	Barley 	Corn 	Soy 	Rapeseed 	Sunflower 
1	Egypt	4072,4	1599,2	0,0	2075,5	383,7	13,9	0,0
2	Turkey	2929,4	362,6	1,1	1450,8	917,4	197,2	0,3
3	Spain	2630,8	939,2	2,3	1586,7	43,4	59,4	0,0
4	Italy	2456,8	698,5	3,9	1426,6	279,4	48,4	0,0
5	Algeria	2047,7	1604,4	0,0	418,9	24,4	0,0	0,0
6	Netherlands	1667,5	194,4	3,9	992,1	418,1	58,5	0,4
7	Indonesia	1090,8	258,8	0,0	831,8	0,0	0,1	0,0
8	Vietnam	822,8	301,9	0,1	520,9	0,0	0,0	0,0
9	Tunisia	747,5	422,6	5,5	290,1	23,0	6,4	0,0
10	Yemen	713,4	450,3	1,6	261,5	0,0	0,0	0,0
11	Lebanon	699,8	284,4	8,1	332,9	73,1	1,1	0,1
12	Germany	675,8	239,6	2,7	53,5	177,2	202,2	0,4
13	Bangladesh	591,3	535,6	0,0	55,2	0,0	0,5	0,0
14	India	521,6	11,9	0,0	498,1	0,0	11,6	0,0
15	Republic of Korea	501,5	102,9	0,1	300,4	48,3	49,9	0,0
16	Poland	423,7	16,7	14,9	63,5	126,3	202,3	0,0
17	Greece	418,2	165,1	0,4	111,3	75,6	65,8	0,0
18	Libya	404,3	105,3	26,3	200,3	55,8	16,8	0,0
19	Belgium	401,1	12,1	0,4	185,9	80,0	122,6	0,0
20	France	391,6	56,7	0,3	126,7	134,3	32,4	41,2
21	Israel	338,4	59,2	15,4	261,8	1,7	0,3	0,0
22	China	331,3	12,2	0,6	97,9	6,6	211,5	2,6
23	Cyprus	201,9	50,4	7,9	94,7	46,4	2,4	0,0

24	Iraq	189,2	0,1	0,1	185,8	3,0	0,0	0,2
25	Romania	173,1	7,5	4,0	40,9	99,4	20,9	0,4
26	Great Britain	157,5	1,2	2,8	99,7	4,7	48,6	0,5
27	Syrian Arab Republic	128,5	112,1	0,0	10,5	0,0	5,8	0,0
28	Bulgaria	122,1	0,4	1,9	87,2	21,4	10,9	0,2
29	Oman	121,7	0,0	0,0	121,7	0,0	0,0	0,0
30	Thailand	120,0	0,3	0,0	119,7	0,0	0,0	0,0
	Other countries	1659,7	382,6	48,0	794,2	290,1	131,1	13,7
	TOTAL	27751,5	8988,2	152,4	13696,8	3333,4	1520,6	60,1

Source: Verkhovna Rada of Ukraine (2025), Kyiv School of Economics (2025)

The five main importing countries of Ukrainian wheat were Algeria, Egypt, Spain, Italy and Bangladesh; barley – Libya, Israel, Poland, the USA and Lebanon; corn – Egypt, Spain, Turkey, Italy and the Netherlands. Soybeans were exported mainly to Turkey, the Netherlands, Egypt, Italy and Germany; rapeseed – to China, Poland, Germany, Turkey and Belgium; and sunflower seeds – to France, Azerbaijan, China, Kazakhstan and Georgia. In addition, during the past year, Ukraine actively exported processed products, in particular oilseeds, to various countries of the world. Sunflower oil, for example, was exported to over 125 countries, the main consumers of which were Turkey, Italy and Egypt (Table 2).

Tab. 2

Top 15 exporting countries of Ukrainian oil in 2025

No	Country	Together		Sunflower 		Soy 		Oil cake is different 	
		thousand tons	%	thousand tons	%	thousand tons	%	thousand tons	%
1	Turkey	4050,2	22,1	3811,1	29,2	46,8	4,5	192,2	4,5
2	China	1854,8	10,1	137,2	1,1	359,8	34,6	1357,7	31,8
3	Italy	1686,1	9,2	1516,6	11,6	5,8	0,6	163,7	3,8
4	Egypt	1221,7	6,7	1144,4	8,8	29,8	2,9	47,5	1,1
5	Netherlands	1069,4	5,8	855,7	6,6	4,6	0,4	209,1	4,9
6	Spain	984,4	5,4	886,8	6,8	18,0	1,7	79,6	1,9
7	Poland	901,4	4,9	38,1	0,3	261,6	25,2	601,7	14,1
8	Lebanon	525,4	2,9	451,3	3,5	9,0	0,9	65,1	1,5
9	Libya	433,8	2,4	358,5	2,8	0,2	0,0	75,1	1,8
10	Germany	412,2	2,2	217,0	1,7	17,9	1,7	177,2	4,2
11	France	358,1	2,0	80,9	0,6	0,0	0,0	277,2	6,5
12	Belgium	350,3	1,9	283,0	2,2	0,5	0,1	66,8	1,6
13	Israel	337,0	1,8	288,6	2,2	0,6	0,1	47,8	1,1
14	Algeria	332,1	1,8	331,7	2,5	0,0	0,0	0,4	0,0
15	Indonesia	315,3	1,7	315,3	2,4	0,0	0,0	0,0	0,0

Other countries	3508,7	19,1	2316,8	17,8	284,2	27,4	907,8	21,3
TOTAL	18340,9	100	13033,1	100	1038,9	100	4268,9	100

Source: BDO in Ukraine (2025), Ukraine Business News (2025), Latifundist (2025), Popov (2026)

The leaders in the export of Ukrainian meal are China, Poland and France, which together exported about 52.4% of meal/cake from oilseeds. In general, Ukraine exported the above-mentioned crop products and their processing in 2025 to all continents of the world, with the lion's share of exports falling on European countries (Fig. 1).

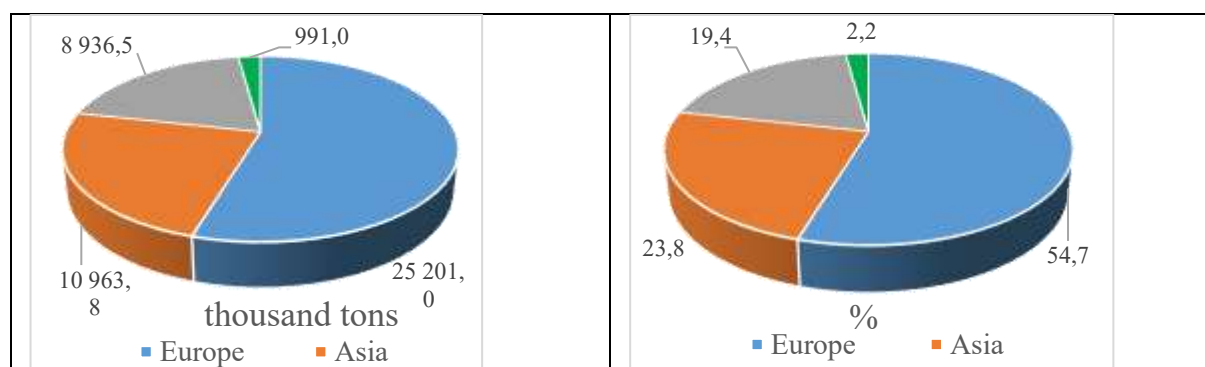


Fig. 1. Structure of continental exports of Ukrainian crop products and products of their processing in 2025

Source: Latifundist (2026)

At the same time, the share of North, South America, and Australia in the export structure is about 2.2% in total.

This continental structure of exports of crop products and their processing products is a consequence of the existing transport logistics that has been formed in recent years. Overall, Ukraine's transport logistics comprises a comprehensive system for planning, organizing, and managing the movement of goods, integrating infrastructure (roads, ports, railways), vehicles, and delivery processes. It aims to optimize transport routes and costs while ensuring timely delivery from the manufacturer to the end consumer. Prior to the war with Russia, Ukraine's transport logistics sector was developing quite dynamically. There was progress not only in transportation modes but also in loading/unloading and warehousing processes; electronic systems for customs clearance and freight forwarding were being developed, and the cargo insurance system was being improved. In this way, transport logistics sought to minimize costs and delivery times, allowing for the selection of the best mode of transport. The infrastructure included rail ("Ukrzaliznytsia"), road, sea (the ports of Odesa, Mykolaiv, and the Danube), river, and air transport. Supporting infrastructure developed near the ports, and potential investors, particularly agricultural holdings, planned to expand these transportation routes through the construction of additional terminals.

Transport and logistics companies in Ukraine supported foreign trade, which allowed for an increase in the share of exports, particularly of agricultural products. Thus, at the beginning of 2022, 98% of agricultural products were sold via the sea corridor, and only 2% by road, ferry and rail transport (Fig. 2). However, in recent years of the war in Ukraine, logistics channels have changed depending on military and political actions.

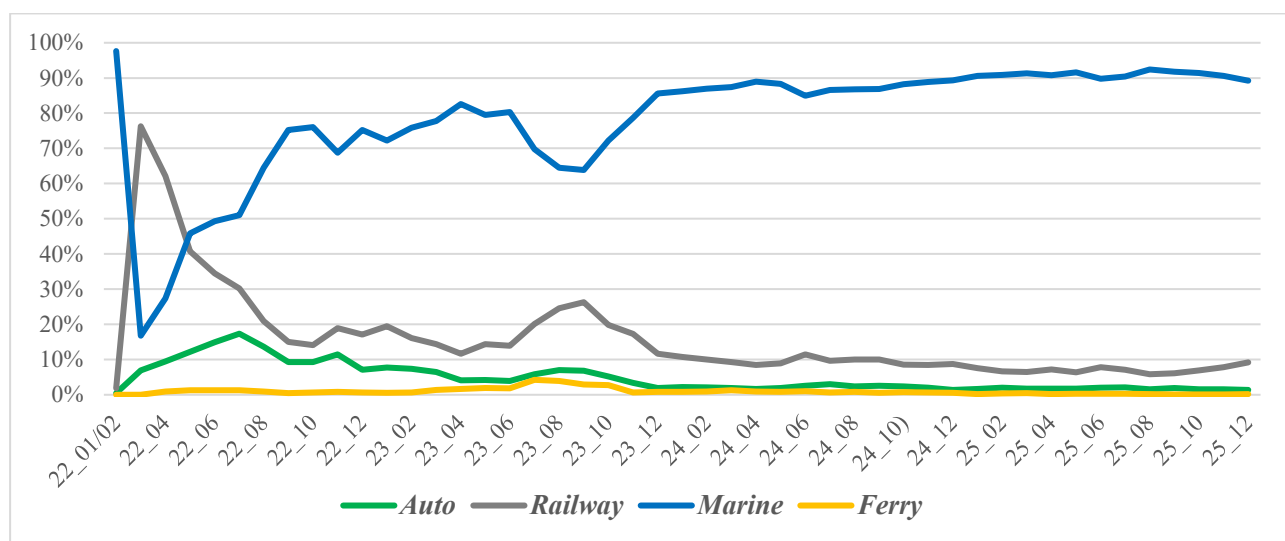


Fig. 2. Structure of export logistics channels for the sale of Ukraine crop production and products of its processing by mode of transport, January 2022 - December 2025

Source: State Statistics Service of Ukraine (2025), Ukraine Business News (2025), Latifundist (2026)

In particular, in the 2023/24 marketing year, an average of 80% of agricultural products were sold through the ports of Ukraine (about 49% through the ports of Odessa, 31% – the ports of the Danube), 5% fell on road transport, and 15% - on rail. However, already in 2025, 90% of products were sold through ports, 9% - by rail, 1% - by road. It is worth noting that in recent years, Ukraine has not been using air transport – a key component of its logistics infrastructure – because its airspace has been closed due to the war. Within individual types of products, the structure of sales channels by mode of transport looks as follows (Table 4).

Tab. 4
Structure of sales channels for individual types of products in 2022-2025, %

Product	Type of transport			
	motor transport	iron	marine	ferry
Wheat	2	6	91	1
Barley	2	3	94	1
Corn	2	13	85	0
Soy	9	20	69	2
Rapeseed	10	22	67	1
Sunflower	28	11	58	3
Soybean oil	34	54	10	2
Sunflower oil	11	13	73	3
Soybean and sunflower meal	4	24	69	3

Source: State Statistics Service of Ukraine (2025), Latifundist (2026)

Price fluctuations profitability on the world market affect of Ukrainian grain exports, so market participants need to develop risk management strategies. In addition, competition from other major global grain producers, such as the USA, Australia, Canada, EU countries, the RF and Argentina, increases pressure on Ukraine to increase its competitiveness through innovation and efficiency.

Analysis of export sales channels for certain types of Ukrainian agricultural products indicates that due to military-political factors and import restrictions, the main points of export of Ukrainian agricultural products in the 2023/2024 marketing year were, in particular:

- ports: Black Sea Sea Port – 21.0% of total exports, Yuzhny Port – 15.2%, Izmail Commercial Sea Port – 14.2%, Odessa Commercial Sea Port – 13.95%, Reni Commercial Sea Port – 8.9%;
- land transport crossing points: Volodymyr-Volynskyi-Khrubeshov – 4.1%, Chop-Zagon-Cherna nad Tysoyu – 3.0%, Yagodyn-Dorohusk – 2.24%, Saluvka-Eperishke – 1.67%, Vadul-Siret-Viksany – 1.65%, Mostyska-Przemysl – 1.51%, Porubne-Siret – 1.25%.

In 2025, the structure changed somewhat, in particular, the Black Sea Sea Port accounted for 39% of agricultural cargo turnover, the Southern Port – 28%, the Odessa Commercial Sea Port – 20%, the Izmail Commercial Sea Port – 3%, all other land crossing points – 10%. In general, the total export share of agricultural products by transition countries in 2022-2025 was as follows: WORLD – 64.1%, Romania – 21.9%, Poland – 7.9%, Hungary – 4.7%; Moldova – 0.9%; Slovakia – 0.5%. Thus, entropy has had a significant impact on the change in sales channels in recent years. It is obvious that such a structure of export channels could have affected Ukraine's position in the world ranking of agricultural products. Therefore, we will study this phenomenon and analyze the exporting countries possible influence on the prices formation for agricultural products. For analysis, we will take the situation on the market of the main 3 export-oriented crops in Ukraine: wheat, corn and soybeans. According to official information from the UN Comtrad database website, in 2022-2025, quite a number of countries were represented in the relevant markets, in particular, 101 countries in the world were engaged in wheat trade, 115 – in corn and 107 countries - in soybeans. However, the sales volumes, prices and market shares of each country vary significantly (Table 5).

Tab. 5

TOP-8 wheat, corn and soybean exporting countries in 2022-2025*

	Country	Export volume, tons	Export value, thousand \$	Weighted average export price, \$/t	Market share by export volume, %
Wheat					
1	Australia	96 432 283	29 698 990	303,3	16,60
2	Canada	91 206 837	30 158 000	340,6	15,70
3	USA	75 148 034	24 087 776	324,9	12,94
4	Ukraine	58 482 164	11 650 331	211,6	10,07
5	France	43 918 621	13 636 748	304,0	7,56
6	Romania	27 712 005	7 690 473	286,2	4,77
7	Germany	24 322 927	6 994 684	289,1	4,19
8	Argentina	24 263 046	7 093 493	305,7	4,18

Corn					
1	USA	222 978 176	59 687 166	274,5	30,84
2	Brazil	169 859 391	40 109 236	259,3	23,49
3	Argentina	111 022 591	25 880 203	237,2	15,35
4	Ukraine	94 017 561	18 860 039	206,3	13,00
5	Romania	15 112 030	4 993 525	331,7	2,09
6	Paraguay	13 544 144	2 704 680	203,7	1,87
7	Poland	13 404 906	3 769 869	280,3	1,85
8	France	12 314 466	6 017 015	473,1	1,70
Soybean					
1	Brazil	362 564 434	173 425 008	483,9	57,62
2	USA	181 392 526	98 442 269	545,3	28,83
3	Paraguay	23 148 621	10 169 170	460,9	3,68
4	Argentina	18 189 712	8 665 045	526,7	2,89
5	Canada	16 193 366	8 964 234	620,3	2,57
6	Ukraine	11 406 206	4 487 170	410,7	1,81
7	Uruguay	3 840 217	2 336 278	622,8	0,61
8	Nigeria	2 715 037	413 541	563,3	0,43

Note: *The model lacks information on export operations of Russia, which has closed official statistics.

Source: State Statistics Service of Ukraine (2025), Latifundist (2026)

According to the results of wheat trade in 2022-2025, the leaders in sales were Australia, Canada, the USA and Ukraine. These 4 countries covered about 55% of the world's wheat demand, and the TOP-8 – about 76%. However, it is worth noting that among these countries, Ukrainian grain had the lowest cost per ton. Thus, wheat from Australia and France cost an average of 43% more, from Canada – 61%, and from the USA – 53.5% more than wheat from Ukraine. A detailed analysis of the price on the wheat market showed that Ukrainian wheat is one of the cheapest in the world due to artificial military entropy and the turbulent environment in Ukraine. A similar situation is observed in the corn market: Ukraine is among the four leaders, covers about 13% of world demand, and price is quite low (among the TOP-8, the price is lower only for corn from Paraguay). Ukraine is not a major player in the soybean market, but it ranks 6th in sales of this product in the world. In fact, Brazil and the USA are world monopolists and together cover more than 86% of world demand. The situation regarding the price of Ukrainian soybeans is similar to other crops, in particular, the main competitors Argentina and Canada sell soybeans 28% and 51% more expensive than Ukraine, respectively. In general, the prices of the studied grain products are among the lowest in the world.

Consequently, amid the war, Ukraine's transport logistics have partially shifted their focus to the western borders, with a growing emphasis on multimodal transport (the combination of several modes of transport). Today, Ukraine's transport and logistics companies see the future in multimodal transport, as it allows for a significant reduction in transit times and minimizes transportation costs. The analysis conducted is the basis for confirming or refuting the hypothesis.

4. RESULTS

As part of the study, a regression model was formed that describes the dependence of the average selling price of wheat (Y) on a number of factors: export volumes (X_1), the country's position in the list of major exporters (X_2) and the role of intermediaries in trade transactions (X_3). Trade transactions for the wheat sale on the world market from January 2022 to December 2025 inclusive were analyzed.

Taking into account the information received, the model was obtained:

$$Y = a_0 + a_1 * X_1 + a_2 * X_2 + a_3 * X_3 \quad (8)$$

where Y is the average selling price of wheat when exported, \$/t;

X_1 is the volume of wheat exports by the corresponding country to another country in the world. From the total sample of observations, export transactions with a volume of more than 10 t were selected (12,360 export transactions were taken into account);

X_2 is the country's place in the TOP-5 in the formation of the average export price. Wheat export transactions in countries such as Australia, Canada, the USA, France and Ukraine were marked in the model as "0" (5,408 export transactions), and transactions from other countries of the world were marked as "1" (6,952 such transactions were identified). The TOP-5 of these countries in 2022-2025 provided 62.9% of the total wheat market.

X_3 is the place of direct transactions in the formation of the export price. The analysis revealed that when exporting wheat, countries sold directly or through an intermediary country. In total, 7881 wheat export transactions were concluded without intermediaries (index "0" in the model) and 4479 transactions with intermediaries (index "1" in the model). Thus, it was established that in the studied period about 64% of contracts for the export of wheat are concluded without intermediaries, and 36% of contracts have a third party. As a result, we obtained the following matrix:

7,9922	175,003	-5,07642E-07	258,855
18,9815	18,24405741	1,59971E-07	17,8415
0,01045	909,1360613	#N/A	#N/A
43,5305	12356	#N/A	#N/A
107937687,2	10212584638	#N/A	#N/A

where: $Y = 258,86 - 0,0000005 * X_1 + 175,0 * X_2 + 7,99 * X_3$

$R_2 = 0,01046$ or 1,05%

Fisher's exact test (F estimate) – 43,53

Thus, the coefficient of determination (R_2), which is used in statistical models as a measure of the dependence of the variation of the dependent variable on the variation of independent variables, indicates the absence of dependence of the price of wheat on the selected factors. This is obvious, since the price of wheat is formed depending on the general supply and demand, transitional stocks and world consumption. Therefore, the coefficient of determination in this model cannot be high enough. At the same time, $F_{\text{calculated}}$ is greater than F_{critical} , i.e. the model is considered adequate.

Therefore, let's examine the model for the significance of the variables for the model, in particular, calculate the t-test. After the calculation, we obtained the following values:

	a3	a2	a1	a0
t calculation	0,42105	9,59236	-3,17334	14,50858
 t calculation 	0,42105	9,59236	3,17334	14,50858
t crit.	1,960155			

The calculations indicate that the variables X_1 and X_2 are significant to the model, while X_3 is not significant. In addition, the model was tested for multicollinearity and confirmed to be absent.

	X₁	X₂	X₃
X₁	1	-0,138794	-0,187152
X₂	-0,138794	1	-0,372282
X₃	-0,187152	-0,372282	1

Additionally, the correlation coefficient (r) was calculated to analyze the strength of the linear relationship or association between the two variables. Thus, the r between price and sales volume (X_1) is minus 4.37%, price and position in the TOP-5 (X_2) is 9.76%, and between price and place of direct transactions (X_3) is minus 2.56%.

So, in general, the model showed that sales volume does not significantly affect the average sales price, in particular, with an increase in sales volume by 100 thousand tons, the price for the entire batch will decrease by \$ 0.5. In addition, this variable is significant for the model as well as X_2 . The third factor turned out to be insignificant for the model. According to the calculations, it is worth noting that if wheat is not purchased from the main exporting countries (TOP-5), the price per ton will increase by an average of \$175, and wheat exports through an intermediary country increase the price by an average of \$7.99 per ton.

Next, we simulated model No. 2, where instead of X_2 – the places of the TOP-5 exporting countries in pricing, the TOP-10 exporting countries were selected, since they form the world wheat market by 82.4%. The following model matrix was obtained:

-18,2593	179,0296	-4,91296E-07	294,44
17,9451	17,5492	1,59765E-07	14,73
0,01141	908,696	#N/A	#N/A
47,56263	12356	#N/A	#N/A
117821455,2	10202700870	#N/A	#N/A

In fact, the results of the model did not change significantly, $R_2 = 0.0114$ or 1.14%, according to Fisher's criterion, the model is adequate, the t-criterion showed a similar situation as in the previous model, multicollinearity is absent.

Therefore, it was decided to develop model No. 3 with an additional factor based on model 1. The marketing year period was chosen as an additional factor. Thus, in the model, export operations carried out in the first half of the marketing year (July-December) received an index of "0". A total of 5989 such transactions were identified, which is 48.5% of all wheat trade operations. Operations carried out in the second half of the marketing year (January-June) for

the sale of wheat received an index of "1" (6371 transactions or 51.5%). As a result, the following matrix was obtained:

-29,783	5,1565	174,9012	-4,98838E-07	275,100
16,4460	19,0442	18,24246	1,6003E-07	19,968
0,010721	909,0522	#N/A	#N/A	#N/A
33,47383	12355	#N/A	#N/A	#N/A
110647900,2	10209874425	#N/A	#N/A	#N/A

where: $Y = 275,1 - 0,00000049 \cdot X_1 + 174,9 \cdot X_2 + 5,15 \cdot X_3 - 29,78 \cdot X_4$

$R_2 = 0,0107$ or 1,07%

Fisher's exact test (F estimated) is 33.47 and exceeds the critical value.

The result is similar to model No. 1: sales volume (X_1) and the importance of buying from the TOP5 producing countries (X_2) are significant for the model. At the same time, the factors of concluding a contract without an intermediary (X_3) and the choice of the marketing half-year for selling wheat (X_4) are not significant for the model, although the estimated t is close to the critical t . Although it is worth noting that according to the factor X_4 , exporting countries in the second half of the marketing year sell an average of \$29.78 cheaper per ton of wheat than in the first marketing half-year. Thus, we partially confirmed and refuted the hypothesis. It was confirmed that the average export price is affected by the sales volume, in particular, with an increase in the wholesale batch of grain, the price tends to decrease, although this decrease is insignificant. The influence of the TOP producer country on the formation of the price policy for export of products was also confirmed: large producers sell their products in large batches at lower prices than small ones, which trade in local markets in small volumes. Regarding intermediaries in grain trade and the period of the marketing year, the hypothesis was not confirmed, since the factors were recognized as insignificant. However, given the proximity of the calculated value to the critical one by the X_4 factor, it can be assumed that in the second half of the marketing year grain products become cheaper due to the risk of losses on the market due to the potential increase in yield in the next marketing year.

Therefore, we recommend taking into account the influence of these factors when developing possible scenarios for the development of grain trading in Ukraine in the context of anti-entropic measures. Many experts note that the Ukrainian grain market has significant opportunities for growth and development, which can be used to increase the competitiveness of the sector. Emerging markets in Asia and Africa have significant potential for Ukrainian grain exports, opening up new avenues for diversifying supply. This is also confirmed by analytical materials on the sales volumes of Ukrainian products over the past 4 years. Technological progress in precision agriculture, digital technologies and agro-technological solutions provides opportunities for the implementation of smart technologies to increase productivity, ensure sustainable grain production and track the movement of agricultural products along the supply chain. Diversification strategies, such as expanding value-added or organic grain production, can help Ukrainian producers capture market niches and increase profitability. To ensure the sustainability of the Ukrainian grain market, policymakers and stakeholders need to collaborate on project implementation and strategic planning. Investments in infrastructure development, including storage facilities and transport networks, are important to overcome logistical challenges and ensure effective supply chain management, especially given that Ukraine sells its products at low prices. A significant problem in the modern grain market is high operational risk.

The implementation of risk management mechanisms to mitigate these risks is a key opportunity to support the development of the sector and protect the interests of grain producers and exporters. In addition, promoting research and innovation in the agricultural sector can stimulate technological progress and increase the resilience of the Ukrainian grain market in the face of new challenges. A comparative analysis of the Ukrainian grain market with other major grain-producing countries reveals both competitive advantages and areas for improvement. Compared with countries such as the United States, France, or Germany, Ukraine is distinguished by the quality of its land resources, large arable areas, lower production costs, and rapid growth in agricultural productivity. These factors increase Ukraine's competitiveness in the global grain market, contribute to increased export volumes and access to new markets, and provide the opportunity to trade at lower prices in the short term. However, issues such as infrastructure deficiencies and regulatory constraints highlight opportunities for improvement to increase the overall efficiency and sustainability of Ukraine's grain market in line with global standards.

Global market trends, including changing consumer preferences, trade disputes, and geopolitical tensions, play a significant role in shaping the future trajectory of the Ukrainian grain market. Changes in consumer preferences for healthier and more environmentally friendly foods are affecting grain demand, impacting production and marketing strategies in Ukraine. Trade disputes and geopolitical tensions between major grain-producing countries can disrupt market dynamics, affecting export opportunities and pricing strategies of Ukrainian grain exporters. Stakeholders in the Ukrainian grain market should closely monitor these global trends and adapt accordingly to maintain competitiveness. Market volatility, regulatory changes, and environmental concerns significantly affect the development and sustainability of the Ukrainian grain market. Fluctuations in grain prices can affect the profitability of producers and exporters, highlighting the need for risk management strategies and market diversification to mitigate financial risks. This is especially important in the context of the war that Russia has waged against democratic societies, which is a major factor in the entropy in the Euro-Atlantic space. Regulatory changes, both domestic and international, may affect market access, trade agreements, and compliance requirements, requiring adaptation and compliance by Ukrainian grain market participants. Environmental issues such as climate change and sustainable agricultural development are becoming increasingly important factors in the global grain market, requiring investments in environmentally friendly technologies and practices to ensure the long-term viability of grain production in Ukraine.

Thus, the current state and development of the grain market in Ukraine underlines the significant role of the country as a major grain producer and exporter. An examination of key aspects such as production levels, export trends, influencing factors, challenges, opportunities for growth, and recommendations for improvement reveals both strengths and areas for improvement. To enhance competitiveness and sustainability, policymakers and stakeholders should focus on addressing infrastructure constraints in grain logistics, implementing risk mitigation strategies, and seizing growth opportunities. By leveraging its competitive advantages, adapting to changing market dynamics, and prioritizing long-term sustainability, Ukraine's grain market can position itself for continued success in the global agricultural landscape.

Over the past four years, the conditions of economic activity in the agricultural sector of Ukraine have changed significantly as a result of the armed aggression of the Russian Federation. The artificial entropy of a military nature has highlighted the following conditions:

- blocking of Ukrainian ports, warehouses, granaries and the impossibility of exporting Ukrainian products, which has negatively affected sales opportunities and prices;

- complications or impossibility of transport movement in the combat zone, disruption of production chains;
- shortage and rapid growth of fuel prices;
- withdrawal of equipment for military needs, mobilization of personnel to the armed forces;
- damage and theft of fixed assets and stocks of production resources, finished products in the combat zone;
- lack of working capital;
- agricultural fields and roads mined or littered with explosive objects;
- prohibition of movement during curfew.

At the same time, the Government and the Verkhovna Rada of Ukraine have taken a number of measures to support agricultural entrepreneurs by providing benefits, partial loan guarantees, export support, simplifying imports, covering insurance payments, reducing regulatory restrictions, etc. Such measures should simplify economic activity and ensure access to financial and production resources.

An important factor in the efficiency of grain trade is the dynamics of product prices. The interaction between world demand and supply largely determines pricing in the grain market in the country. When demand exceeds supply, prices tend to increase, which reflects a shortage of available grain. Conversely, when supply exceeds demand, prices tend to decrease. The dynamics of world demand and supply for food and feed significantly affects price stability in this region of our country. Ukraine has a developed and competitive agricultural market, which is closely linked to the world market, and therefore is a vivid example of this. Despite the fact that the Ukrainian market is saturated with domestically produced food products, their prices still depend on fluctuations in the world market.

This is due to several key factors:

- modern world markets are closely interconnected - this means that events occurring in one country can affect prices in other countries;
- the growth of international trade in agricultural and food products makes world prices changes more sensitive in demand and supply in a particular country;
- speculation in futures markets can lead to some increase or decrease in prices.

The impact of global demand and supply dynamics on the stability of food prices in Ukraine can have both positive and negative consequences. On the one hand, this can lead to better food security for the population and a more flexible response to changes in demand. On the other hand, it can lead to price instability, which negatively affects household budgets and can lead to social unrest.

In fact, geopolitical events also play a decisive role in shaping and transforming global grain trade chains and flows, directly affecting the dynamics of global grain trade. Restrictions caused by conflicts, trade embargoes and sanctions can lead to significant trade deviations or even a complete cessation of trade with certain countries. These events often cause immediate shortages or surpluses of grain in certain regions, which leads to a sharp increase or decrease in prices and a decrease/increase in the economic efficiency of trade. In addition, the uncertainty associated with geopolitical instability can hinder investment in infrastructure, which, in turn, further exacerbates the problems of maintaining stable and efficient grain trade systems. Therefore, the war in Ukraine has increased the risks of conducting economic activities, which in turn has affected the decline in export prices. The logistical lever has taken away income from producers and has become an additional price for export risk.

Exchange rates and their changes are also an important factor in international grain trade, affecting the competitiveness and profitability of trading activities. Currency fluctuations can change grain prices in different markets, affecting the dynamics of supply and demand, as well as the efficiency of trade. Changes in the exchange rate of a grain-exporting country can significantly affect its export opportunities. A weakening currency makes grain exports more profitable, which can lead to increased demand and increased export volumes. Conversely, a strengthening currency makes grain exports more expensive and can reduce their competitiveness in the international market. This interdependence between exchange rates and grain trade highlights the financial markets importance in the global agricultural economy, affecting the level of economic efficiency of grain trade. The impact of government subsidies and tariffs on domestic grain production cannot be overstated, as they significantly shape the economic landscape for both farmers and the agricultural sector as a whole. Subsidies, often viewed as financial assistance from the government, are intended to reduce the cost burden on producers, allowing them to sell grain at competitive prices while maintaining profitability. Such financial support can lead to increased grain production, making it more economically viable for producers and traders. Tariffs on grain imports serve as a protection for domestic producers from foreign competition, as they ensure that local markets are not undermined by cheaper imports.

Import and export restrictions play an important role in determining trade volumes, significantly influencing the dynamics of the world grain market. These restrictions imposed by the government can either hinder or stimulate the flow of grain across borders. The consequences of export and import restrictions for the grain market are as follows:

1. Export restrictions can lead to a surplus of grain on the domestic market and lower prices. This is roughly indicated by the X_4 of model 3 of our study. This can negatively affect producers' incomes and the country's trade balance. At the same time, they stimulate the development of the domestic processing sector and can lead to increased trade in agricultural products on the domestic market.
2. Import restrictions can lead to a decrease in the availability of foreign grain, which can lead to an increase in prices on the domestic market. This may be beneficial for local producers, but not for foreign sellers. Import restrictions can lead to retaliatory measures from trading partners, which can negatively affect the volume and efficiency of grain trade in general.

This dynamic highlights the complexity of trade policy and its direct impact on the economic efficiency of grain trade, which is explored by analyzing the factors affecting changes in the efficiency of grain market functioning.

Global warming is changing producers' access to natural resources, which also affects the efficiency of agricultural trade. Water scarcity is a major challenge for maintaining and improving irrigation, the basis of grain production in many regions of the world. Irrigation and water management are becoming critically important in the context of decreasing water resources. As water becomes increasingly scarce, the agricultural sector must adapt to meet the needs of a growing population with grain production. This adaptation involves not only the implementation of more efficient irrigation technologies and practices but also a holistic management approach that considers the entire water use cycle, from source to use. In addition, important strategies to mitigate the impact of water scarcity on grain production include the development of crop varieties that require less water and the implementation of cropping patterns that better match water availability patterns. These measures not only help to maintain production levels, but also contribute to the economic efficiency of grain trade by stabilizing supplies and prices. In addition, in many countries, river transport is a poor way to transport

grain, and the shallowing of such rivers can have negative consequences for the ability to deliver grain cargoes. Technological advances, such as automation and optimization of logistics, the use of modern management systems and forecasting, play a key role in increasing efficiency by preserving grain quality, reducing losses, speed and cost of transportation. In addition, smart management of financial resources, including minimizing costs and mitigating risks, is crucial for maximizing profits and ensuring sustainable development. Understanding and analyzing price trends, adapting pricing policies, and taking into account global and local factors are mandatory to respond to market fluctuations. In addition, the impact of government policies, government support programs and the competitive environment further affect the economic efficiency of grain trade. By exploring these multifaceted factors, our subsequent research will aim to explore in more depth how each aspect affects the level of economic efficiency of grain trade. Internal factors - effective management and qualified personnel, the use of modern technological equipment - are factors that increase the economic efficiency of grain trade and should adequately respond to turbulent flows and entropy in general. In addition, energy-efficient technological equipment allows for significant reductions in the costs of transshipment, cleaning and storage of products. Such cost reduction is not only a matter of saving money, it directly translates into competitive prices on the market, which allows producers to offer grain at more attractive prices without harming the grain trader's profit. In addition, increased management efficiency, due to modern technological solutions, directly contributes to increased productivity. Studies of economic efficiency further emphasize that technologies affect not only production, but also the stages of grain processing and trade, since the benefits of investments in modern technologies permeate the entire grain value chain. And this is one of the important anti-entropic directions.

Ultimately, the mechanism for increasing production efficiency in agricultural enterprises largely depends on the introduction of these technological tools into trade, demonstrating a clear path to increasing economic efficiency through technology. Thus, in the context of grain trade, technological equipment becomes a key factor not only for reducing costs, but also for increasing productivity and competitiveness in the market. After discussing the impact of technological factors on the economic efficiency of grain trade, it is important to highlight the role of financial factors in increasing this efficiency. Financial resources are indispensable in various aspects of grain trade, from procurement to logistics. For example, the ability to increase grain procurement volumes during periods of price decline is a strategic advantage that requires significant financial resources. This strategy not only ensures a stable supply of grain, but also maximizes profitability due to lower prices, which is consistent with the models of our study. In addition, financial resources are necessary for the adoption and implementation of new logistics strategies in grain transportation, which can lead to significant cost savings. As some researchers have noted, the introduction of new logistics could save Ukraine approximately 3 billion hryvnias annually, which highlights the potential financial benefits that can be achieved through effective resource management. In addition, the expansion of credit systems, particularly through commercial banks, plays a key role in improving access to credit for grain traders.

5. CONCLUSIONS

In summarizing the current challenges and opportunities for the development of Ukraine's grain trade in the context of anti-entropy, we identify a number of trends that should be taken into account in the future as the grain trade evolves, specifically:

1. Factors influencing the level of economic efficiency of grain trade are multifaceted and interrelated. The war in Ukraine has become a defining factor in the development of grain trading, as it significantly shapes transportation and logistics policies, influences grain distribution channels and methods, and hinders investment in transportation infrastructure. At the same time, the war affects the distribution of income between producers and grain traders, as it is the grain traders who currently bear the main risks associated with product sales.
2. Factors influencing the level of economic efficiency of grain trade are multifaceted and interrelated. It is impossible to overestimate the critical role of management efficiency and personnel qualifications in increasing the competitiveness and efficiency of grain trade operations. Effective management methods are important for directing grain production towards profitability and sustainable development, encompassing strategic oversight and operational execution. In addition, employee qualifications directly affect production efficiency and labor productivity in the grain industry, laying the foundation for regulatory compliance, business evaluation, and the implementation of innovative approaches. Ukraine has partially lost its potential for developing a skilled workforce due to the migration of Ukrainians to other countries as a result of the military conflict.
3. The use of modern technologies in grain trade allows producers to significantly reduce production costs, and the expansion of credit systems, in particular through commercial banks, expands traders' access to credit. This will be facilitated by further improvements not only to distribution channels and transportation vehicles, but also to loading/unloading and warehousing processes, as well as the systematic development of electronic customs clearance systems, freight forwarding services, and cargo insurance systems.
4. The use of modern technologies in grain trade allows producers to significantly reduce production costs, and the expansion of credit systems, in particular through commercial banks, expands traders' access to credit. According to the developed correlation models and the influence of individual factors, it can be assumed that by strategically allocating financial resources, grain traders can implement cost-effective procurement strategies, invest in logistics and improve the availability of credit, thereby increasing economic efficiency. This highlights the key role of financial management in addressing challenging grain market conditions and creating an environment conducive to innovation and sustainable growth, which impacts the economic efficiency of grain trading.
5. The specialization of Ukrainian agricultural producers and the long-standing experience of grain traders have shaped traditional sales channels for grain products, which will continue to develop. At the same time, the increase in grain production in Ukraine makes it possible to supply new markets with high-quality products. Therefore, in the future, in addition to the traditional buyer countries of Ukrainian grain, we can expect an expansion of sales into Asian and African markets. At the same time, Ukrainian legislation is implementing EU standards for agricultural production, which indicates the priority of developing grain production in the context of Ukraine's accession to the EU.

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References

1. Andreichenko Andrii, Serhii Zhurylo. 2025. "Decision-making in agribusiness management." *Scientific Bulletin of the Odessa National Economic University* 2(327): 65-72. ISSN: 2409-9260. DOI: 10.32680/2409-9260-2025-2-327-65-72.
2. Andriushchenko Kateryna, Mykola Ishchenko, Mykhailo Sahaidak, Mariia Tepliuk and Oksana Domina. 2019. "Prerequisites for the creation of financial and credit infrastructure of support for agricultural enterprises in Ukraine." *Banks and Bank Systems* 14(2): 63-75. ISSN: 1816-7403. DOI: 10.21511/bbs.14(2).2019.06.
3. Atamanyuk Igor, Valerii Havrysh, Vitalii Nitsenko, Oleksii Diachenko, Mariia Tepliuk, Tetiana Chebakova, Hanna Trofimova. 2023. "Forecasting of Winter Wheat Yield: A Mathematical Model and Field Experiments." *Agriculture* 13(1): 41. ISSN: 2077-0472. DOI: 10.3390/agriculture13010041.
4. Bazaluk Oleg, Marina Postnikova, Serhii Halko, Serhii Kvitka, Evgeniy Mikhailov, Oleksandr Kovalov, Olena Suprun, Oleksandr Miroshnyk, Vitalii Nitsenko. 2022. "Energy Saving in Electromechanical Grain Cleaning Systems." *Applied Sciences* 12(3): 1418. ISSN: 2076-3417. DOI: 10.3390/app12031418.
5. BDO in Ukraine. 2025. "Oilseed Market of Ukraine 2025: Analysis, Trends, Development Forecast." Available at: <https://www.bdo.ua/en-gb/insights-1/information-materials/2025/oilseed-market-ukraine-2025-trends-analysis-forecast>.
6. Belkin Ihor, Sofiia Trapaidze, Valerii Bondarenko, Oleksandr Omelianenko, Ivan Cherniavskiyi. 2025. "Sustainable Marketing of Ukrainian Agricultural Enterprises to Enter Global Grain Markets". *European Journal of Sustainable Development* 14(2):490. ISSN: 2239-5938. DOI: 10.14207/ejsd.2025.v14n2p490.
7. Bilokon Mykhailo. 2025. "Entropy as a Challenge to the Institutional Sustainability of Public Administration in the Conditions of Hybrid Threats." *Pressing Problems of Public Administration* 1(66): 179-195. ISSN: 1684-8489. DOI: 10.26565/1684-8489-2025-1-08
8. Burg Andrew. 2023. "Entropy in the logistics world. Applying Boltzmann's Equation to Modern Logistics: A Blend of Physics and Efficiency." *Transvirtual*. Available at: <https://www.transvirtual.com/blog/entropy-in-the-logistics-world/>.
9. Burkovska Anna, Olena Shebanina, Tetyana Lunkina, Alla Burkovska. 2021. "Ensuring food security in the context of the sustainable development of agriculture." *Management Theory and Studies for Rural Business and Infrastructure Development* 43(3): 337-345. ISSN: 2345-0355. DOI: 10.15544/mts.2021.30.
10. Decker Eric A., Devin J. Rose, Derek A. Stewart. 2014. "Processing of oats and the impact of processing operations on nutrition and health benefits." *British Journal of Nutrition* 112: S58-S64. ISSN: 0007-1145. DOI: 10.1017/S000711451400227X.
11. Denysiuk Olena, Ihor Svitlyshyn, Iryna Tsaruk, Olga Vikarchuk, Andrii Dankevych. 2022. "Diversification in the enterprises' activities for sustainable development in the agricultural sector." *Rivista di studi sulla sostenibilita* XII(2): 85-102. ISSN: 2239-1959. DOI: 10.3280/RISS2022-002007.

12. Dibrova A., L. Stepasiuk. 2023. "Economic value and economic attractiveness of oats in the context of the development of a niche production." *Economics and business management* 14(3): 53–65. ISSN: 2707-3823. DOI: 10.31548/economics14(3).2023.045.
13. Durowoju Olatunde Amoo, Hing Kai Chan, Xiaojun Wang. 2012. "Entropy assessment of supply chain disruption". *Journal of Manufacturing Technology Management* 23(8): 998-1014. ISSN: 1741-038X. DOI: 10.1108/17410381211276844.
14. Gonzalez-Bueno Jairo, Fernando García, Jose Garces-Baustista, Javier Oliver, Rima Tamošiūnienė. 2024. "A multi-objective credibilistic approach to portfolio optimization: balancing return, risk, and liquidity in emerging and developed markets." *Intellectual Economics* 18(2): 284-307. ISSN: 1822-8011. DOI: 10.13165/IE-24-18-2-03.
15. Holopainen-Mantila Ulla, Kaisa M. Linderborg, Vieno Piironen, Tuula Sontag-Strohm, Emilia Nordlund. 2023. "Oats." In: *ICC Handbook of 21st Century Cereal Science and Technology*: 173-180. ISBN: 978-0-323-95295-8. DOI: 10.1016/B978-0-323-95295-8.00018-6.
16. Hutorov Andrii, Yurii Lupenko, Oleksii Yermolenko, Oleksandr Dorokhov. 2018. "Strategic Management of the Agrarian Sector of Economy based on the Analysis of Value Chains." *Bulletin of the Transilvania University of Brasov. Series II: Forestry, Wood Industry, Agricultural food Engineering* 11(60/2): 101-114. ISSN: 2065-2135. Available at: https://webbut.unitbv.ro/index.php/Series_II/article/view/693/627.
17. Ilchenko S. V. 2025. "Indicative model of the eco-adaptive modernization of Ukraine's transport and logistic network." *Naukovyi Visnyk Natsionalnoho Hirnychoho Universytetu* 6: 246-259. ISSN: 2071-2227. DOI: 10.33271/nvngu/2025-6/246.
18. Jablonskis Alvydas. 2014. "Explications and Interpretations of Logistic Activity." *Intellectual Economics* 8(1): 47-58. ISSN: 1822-8011. DOI: 10.13165/IE-14-8-1-07.
19. Karimzada Mehriban Vaqif. 2020. "Features of ensuring food security." In: *Economic and Social Development: Book of Proceedings; Varazdin*: 2-4. Available at: <https://www.proquest.com/openview/17bd6fffa208db6ede358c92c36562bd/1?pq-origsite=gscholar&cbl=2033472>.
20. Kim Hye-Ji. 2016. "Opportunities and Challenges of Alternative Specialty Crops: The Global Picture." *Hortscience* 51(11): 1316-1319. ISSN: 2327-9834. DOI: 10.21273/HORTSCI10659-16.
21. Klein Jesse. 2022. "Oatly wants farmers to plant more oats. Here's how it's helping." *Trellis*. Available at: <https://www.greenbiz.com/article/oatly-wants-farmers-plant-more-oats-heres-how-its-helping>.
22. Korol Dmytro. 2025. "Grain Market: How Ukraine Maintains Its Export Positions Despite the War." *BDO in Ukraine*. Available at: <https://www.bdo.ua/en-gb/insights-1/information-materials/2025/ukraine-grain-market-2025>.
23. Kotenko S., V. Nitsenko, I. Hanzhurenko, M. Vasylyuk, Y. Lavrushchenko, I. Kucher. 2021. "The Economic Crisis as a Factor in Changing the Structure of Multimodal Transportation Routes." *Financial and Credit Activity: Problems of Theory and Practice* 6(41): 277-284. ISSN: 2306-4994. DOI: 10.18371/fcaptp.v6i41.251454.
24. Kulakova Svitlana, Alina Kalemбет, Daryna Podkopova. 2023. "Features of the formation of logistics expenses of enterprises under military conditions." *Financial and Credit Systems: Prospects for Development* 1(8): 22-29. ISSN: 2786-4995. DOI: 10.26565/2786-4995-2023-1-03.
25. Kyiv School of Economics. 2025. "AgroDigest Ukraine." Center for Food and Land Use Research (KSE Agrocenter). Available at: https://kse.ua/AgroDigest_Ukraine_January_2025.pdf.

26. Kyryliuk Iryna, Oleksii Liutyi. 2023. Features of management in the agricultural business of Ukraine. *Bulletin of the Cherkasy Bohdan Khmelnytsky national university. Economic sciences* 27(3-4): 68-83. ISSN: 2707-5036. DOI: 10.31651/2076-5843-2023-3-4-68-83.
27. Latifundist. 2025. "TOP-7 countries importing sunflower oil from Ukraine 2024." Available at: <https://latifundist.com/rating/top-7-krayin-importeriv-sonyashnikovoyi-oliyi-z-ukrayini-2024>.
28. Latifundist. 2026. "The end of the first quarter of the century: how the agricultural market will change by 2050 – and where Ukraine is in this story. A large text by Cesar Soares." Available at: <https://latifundist.com/analytics/35-kinets-pershoyi-chverti-stolittya-yak-zminitsya-agrarnij-rinok-do-2050-roku--i-de-v-tsij-istoriyi-ukrayina-velikij-tekst-tsezarya-soaresa>.
29. Liu Linqing, Weiran Wang, Xiaofei Yan, Mengyun Shen, Haizhi Chen. 2023. "The cascade influence of grain trade shocks on countries in the context of the Russia-Ukraine conflict." *Humanit Soc Sci Commun* 10:449. ISSN 2662-9992. DOI: 10.1057/s41599-023-01944-z.
30. Materynska O., O. Klymchuk, T. Kronivets, L. Romanchuk, N. Burlaka, N. 2025. "Sustainable development management: basic principles and tools of influence." *Naukovyi Visnyk Natsionalnoho Hirnychoho Universytetu* 4: 217-226. ISSN: 2071-2227. DOI: 10.33271/nvngu/2025-4/217.
31. Medvediev Levgen, Dmitriy Muzylyov, Jakub Montewka. 2024. "A model for agribusiness supply chain risk management using fuzzy logic. Case study: Grain route from Ukraine to Poland." *Transportation Research Part E: Logistics and Transportation Review* 190: 103691. DOI: 10.1016/j.tre.2024.103691.
32. Mirzoieva Tetiana, Vladyslav Tomashevskiy. 2023. "Justification of the feasibility of developing the production of niche grains." *Economy and Region* 1(88): 17-23. ISSN: 2218-1199. DOI: 10.26906/EiR.2023.1(88).2866.
33. Mykhailichenko Mykola, Olena Lozhachevska, Volodymyr Smagin, Olexander Krasnoshtan, Mykola Zos-Kior, Iryna Hnatenko. 2021. "Competitive strategies of personnel management in business processes of agricultural enterprises focused on digitalization." *Management Theory and Studies for Rural Business and Infrastructure Development* 43(3): 403-414. ISSN: 2345-0355. Available at: <https://ejournals.vdu.lt/index.php/mtsrbid/article/view/2519>.
34. Oishi Koshi, Yota Hashizume, Tomohiko Jimbo, Hirotaka Kaji, Kenji Kashima. 2023. "Resilience Evaluation of Entropy Regularized Logistic Networks with Probabilistic Cost." *IFAC-PapersOnLine* 56(2): 3106-3111. ISSN: 2405-8971. DOI: 10.1016/j.ifacol.2023.10.1442.
35. Osadchuk Valeriia, Olha Yatsenko, Oleksandr Iatsenko. 2024. "Digital imperative and innovations in international trade." *Neuro-Fuzzy Modeling Techniques in Economics* 13: 25-58. ISSN: 2306-3289. DOI: 10.33111/nfmte.2024.025.
36. Ostrovska H. Y., L. S. Verbovska, L. S. Tarayevska, I. B. Haliuk, M. Ju. Petryna. 2025. "Building a technological ecosystem in the context of digital transformation." *Naukovyi Visnyk Natsionalnoho Hirnychoho Universytetu* 4: 195-205. ISSN: 2071-2227. DOI: 10.33271/nvngu/2025-4/195.
37. Otsuka Keijiro. 2013. "Food insecurity, income inequality, the changing comparative advantage in world agriculture." *Agric. Econ.* 44: 7-18. ISSN: 0169-5150. DOI: 10.1111/agec.12046.

38. Ovcharenko Levgen, Olga Khodakivska, Larysa Sukhomlyn, Olena Shevchenko, Iryna Lemeshenko, Andrii Martynov, Mykola Zos-Kior, Iryna Hnatenko, Sergiy Michkivskyy, Liudmyla Bilyavska. 2022. Spatial organization management: modeling the functioning of eco-clusters in the context of globalization. *Journal of Hygienic Engineering and Design* 40: 351-356. Available at: <https://keypublishing.org/jhed/wp-content/uploads/2022/11/32.-Full-paper-Ievgen-Ovcharenko.pdf>.
39. Ovdiiuk Olena. 2025. "Organizational-economic mechanism of managerial decision-making at food industry enterprises." *Economics. Management. Innovations* 2(37). ISSN: 2410-3748. DOI: 10.35433/ISSN2410-3748-2025-2(37)-11.
40. Panfilova Antonina, Anastasiia Poltorak, Anna Kuvshinova, Anna Burkovska, Nataliia Dotsenko. 2025. "Trends in global grain and seed trade, Ukrainian position on the global market." *Scientific Horizons* 28(5): 142-157. ISSN: 2663-2144. DOI: 10.48077/scihor5.2025.142.
41. Pawlak Karolina, Małgorzata Kołodziejczak. 2020. "The Role of Agriculture in Ensuring Food Security in Developing Countries: Considerations in the Context of the Problem of Sustainable Food Production." *Sustainability* 12(13): 5488. ISSN: 2071-1050. DOI: 10.3390/su12135488.
42. Petkevičiūtė-Stručko Monika, Ivanou Yauhen. 2018. "The complexity effect of freight forwarding trade instruments in project logistics." *Intellectual Economics* 12(1): 47-58. ISSN: 1822-8011. DOI: 10.13165/IE-18-12-1-04.
43. Petrunenko Iaroslav, Inna Grabchuk, Tetiana Vlasenko, Elena Petrova, Liudmyla Strikha. 2021. "Ensuring Food Security of Eu Countries in the Context of Sustainable Development." *Journal of management Information and Decision Sciences* 24(3): 1-12. Available at: <https://dspace.mnau.edu.ua/jspui/bitstream/123456789/9364/1/Ensuring-food-security-of-EU-countries-in-the-context-of-sustainable-development-1532-5806-24-3-245.pdf>.
44. Plakantara Sophia P., Athanasia Karakitsiou. 2025. "Transforming Agrifood Supply Chains with Digital Technologies: a Systematic Review of Safety and Quality Risk Management." *Oper. Res. Forum* 6: 113. ISSN: 2662-2556. DOI: 10.1007/s43069-025-00511-3.
45. Popov Andrii. 2026. "At sea and on land. How the "world war" for oil threatens Ukraine and Ukrainians." *UNIAN.UA*. Available at: <https://www.unian.ua/economics/agro/namori-i-na-zemli-chim-svitova-viyna-za-oliyu-zagrozhuye-ukrajini-y-ukrajincyam-13269165.html>.
46. Qin Mingxing, Xinyue Gao, Meichen Feng, Ning Jin, Chao Wang, Wenjuan Cheng. 2022. "Modeling of the potential geographical distribution of naked oat under climate change." *Front. Plant Sci., Sec. Functional Plant Ecology* 13: 1009577. ISSN: 1664-462X. DOI: 10.3389/fpls.2022.1009577.
47. Riepina Inna, Larysa Ligonenko, Oleksandr Sadovnyk, Lyubov Dzyubenko, Vita Kovtun. 2022. "Identification of factors related to transport entrepreneurship influencing the economic development of Ukraine." *Transport Problems* 17(4): 151-163. ISSN: 1896-0596. DOI: 10.20858/tp.2022.17.4.13.
48. Rudik O.L., N.M. Rudik, L.A. Serhieiev, V.V. Chuhak. 2022. "Sowing millet in the system of adaptation of agricultural production to the global current challenges." *Agrarian innovations* 12: 52-59. ISSN: 2709-4405. DOI: 10.32848/agrar.innov.2022.12.9.

49. Sellitto Miguel Afonso, Ismael Cristofer Baierle, Marta Rinaldi. 2025. "Complexity of Supply Chains Using Shannon Entropy: Strategic Relationship with Competitive Priorities." *Applied System Innovation* 8(4): 105. ISSN: 2571-5577. DOI: 10.3390/asi8040105.
50. Sharko Oleksandr, Andrii Buketov, Kostiantyn Klevtsov, Oleksandr Sapronov, Oleksandr Akimov. 2024. "Entropy model for determining the necessary information in the diagnostics of maritime transportation." *Scientific Journal of TNTU (Tern.)* 113(1): 58-70. ISSN: 2522-4433. DOI: 10.33108/visnyk_tntu2024.01.058.
51. Shlapak Alla, Olha Yatsenko, Oksana Ivashchenko, Nataliya Zarytska, Valeriia Osadechuk. 2023. "Digital transformation of international trade in the context of global competition: technological innovations and investment priorities." *Financial and Credit Activity Problems of Theory and Practice* 6(53): 334-347. ISSN: 2306-4994. DOI: 10.55643/fcaptp.6.53.2023.4241.
52. Shubravska Olena, Kateryna Prokopenko. 2022. "Ensuring food security of Ukraine: post-war context." *Economy of Ukraine* 7: 21-42. ISSN: 2522-9303. DOI: 10.15407/economyukr.2022.07.021.
53. Sonar Harshad, Prasad Joshi, Nikhil Ghag, Shashank Kumar, Nabanit Giri. 2025. "Harnessing Industry 4.0 in agri supply chains: a strategy for enhanced sustainability". *Journal of Agribusiness in Developing and Emerging Economies*. DOI: 10.1108/JADEE-03-2025-0117.
54. State Statistics Service of Ukraine. 2025. "Economic statistics / Economic activity / Transport and communications." Available at: <https://www.ukrstat.gov.ua/>.
55. Su Jingke, Anxiong Liu, Hualin Xiao, Kun Luo, Jianren Fan. 2023. "Entropy: An Inspiring Tool for Characterizing Turbulence – Combustion Interaction in Swirling Flames via Direct Numerical Simulations of Non-Premixed and Premixed Flames." *Entropy* 25(8): 1151. ISSN: 1099-4300. DOI: 10.3390/e25081151.
56. Sumets Alexander, Sviatoslav Kniaz, Nelli Heorhiadi, Ruslan Skrynkovskyy, Vasylyna Matsuk. 2022. "Methodological Toolkit for Assessing the Level of Stability of Agricultural Enterprises." *Agricultural and Resource Economics* 8(1): 235-255. ISSN: 2414-584X. DOI: 10.51599/are.2022.08.01.12.
57. Tanklevska Nataliya, Inna Riepina, Olena Tkachenko, Oleh Kuklin. 2020. "Dynamic modeling of agricultural company asset management process." *Bulletin of the National Academy of Sciences of the Republic of Kazakhstan* 4: 129-139. ISSN: 1991-3494. DOI: 10.32014/2020.2518-1467.112.
58. Ukraine Business News. 2025. "Ukrainian exports 2025: Poland, Turkey, and Italy top the list of main trading partners." Available at: <https://ubn.news/ukrainian-exports-2025-poland-turkey-and-italy-top-the-list-of-main-trading-partners/>.
59. Verkhovna Rada of Ukraine. 2025. "Ukraine increased exports of agricultural products in October, according to the Committee on Agrarian and Land Policy." Available at: <https://www.rada.gov.ua/en/news/News/267932.html>.
60. Vlasov Volodymyr. 2025. "Methodology of management accounting in supporting management processes of marketing activities of agricultural enterprises in Ukraine." *Financial and Credit Systems: Prospects for Development* 4(19): 37-47. ISSN: 2786-4995. DOI: 10.26565/2786-4995-2025-4-03.
61. Xue Yongjie, Jinling Yan, Muhammad Mohsin, Ana Mehak. 2025. "Supply chain risks in agri-food systems: a comprehensive review of economic vulnerabilities and mitigation approaches." *Front. Sustain. Food Syst.* 9: 1649834. DOI: 10.3389/fsufs.2025.1649834.

62. Yu Gwangjae, Hyunsuk Baek, John Fowler. 2025. "Operationalizing Entropy in Logistics to Mitigate Congestion: Application to a Semiconductor Wafer Fabrication Facility Layout." *International Journal of Production Research* 63(24): 9776-98. ISSN: 0020-7543. DOI: 10.1080/00207543.2025.2524765.
63. Zhao Rui, Jili Rong, Xinliang Li. 2014. "Entropy and its application in turbulence modeling." *Chin. Sci. Bull.* 59: 4137-4141. ISSN: 1861-9541. DOI: 10.1007/s11434-014-0569-y.
64. Iatsenko Oleksandr, Yatsenko Olha, Dendeberia Daryna. 2024. "Strategising the behavior of exporters in target global markets." *Collection of Scientific Papers "Scientific Notes"* 37(4): 208-221. ISSN: 2415-8518. DOI: 10.33111/vz_kneu.37.24.04.19.131.137.

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