

The Ukrainian wheat market in the system of global food security: Wartime impact research

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ABSTRACT: The proposed study analyzes the transformation of the Ukrainian wheat market under the influence of hybrid and full-scale war during the period 2019–2024. Comparative analysis and market concentration indicators (Herfindahl-Hirschman, Linda, and Gini indices) allowed us to estimate the export volumes of wheat to global markets and, therefore, the impact of the war in Ukraine on global food security. The study's findings indicate that, despite the low market concentration, changes in the volumes and traditional logistical routes of Ukrainian grain exports have increased threats to global food security.

El mercado de trigo de Ucrania en el contexto de la seguridad alimentaria global: un estudio sobre el impacto de la guerra

RESUMEN: El presente estudio analiza la transformación del mercado ucraniano del trigo bajo la influencia de la guerra híbrida y a gran escala durante 2019–2024. Mediante análisis comparativo e índices de concentración de mercado (Herfindahl-Hirschman, Linda y Gini), se estimaron los cambios en los volúmenes de exportación y en las rutas logísticas tradicionales. Los resultados evidencian que, pese a la baja concentración del mercado, las alteraciones en las exportaciones de grano ucraniano han intensificado las amenazas a la seguridad alimentaria mundial, destacando la necesidad de estrategias logísticas adaptativas y medidas de política internacional.

KEYWORDS / PALABRAS CLAVE: Global wheat market, Ukrainian wheat industry, food security, war impact on agriculture / Mercado global del trigo, industria del trigo de Ucrania, seguridad alimentaria, impacto de la guerra en la agricultura.

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1. Introduction

The grain industry of Ukraine, as the leading agricultural sector in the context of the war (February 2022 - present), remains one of the dynamic sectors of the economy, ensuring the development of several related industries. This sector accounts for a significant share of foreign exchange earnings from trade and allows Ukraine to remain a guarantor of global food security on the global grain market. However, the sector is characterized as highly sensitive to changes in the economic environment, determined by the influence of several important factors and cause-and-effect relationships. It is characterized by multi-vector dependence and the ability to be influenced by the tools of hybrid warfare to redistribute spheres of influence on the part of international counterparties to the grain market.

A full-scale war in Ukraine is expected to be prolonged. Therefore, it poses significant challenges for the Ukrainian grain market. Active hostilities and the risks of loss of grain cargo, destruction of production, trade and logistics infrastructure impose significant restrictions on the work of Ukrainian agricultural companies, traders and international stakeholders. Moreover, they lead to a significant transformation of grain to export supply chains and affect the economic situation of the global grain market in times of disturbances.

In terms of content, the transformation of the global economic situation on the grain market under the influence of the war has led to an aggravation of grain shortages in low- and middle-income countries. In general, according to the World Bank (2024) report, prices on commodity markets around the world increased significantly in 2022 due to the war in Ukraine. The influence of war was particularly evident in agricultural commodities, including wheat and oilseeds, where Ukraine and Russia were major global suppliers. If the war had not started, food market prices after the Covid shock would have had a chance to fall, thereby reducing the level of pressure on food security in low- and middle-income countries. According to Mottaleb *et al.* (2022), countries that relied heavily on wheat imports from Ukraine and Russia were particularly vulnerable to trade disruptions caused by the war. These countries include: Lebanon, Yemen, Ethiopia, Tunisia, Somalia, Sudan, Kenya, Egypt, and others. For example, in Ethiopia alone, wheat imports from Ukraine fell by 69.1 % in 2022-2023, amounting to \$165 million. And in the first year of the full-scale war, the drop was 51.4 %, or \$253 million. Such a significant change in wheat supplies (a critically important commodity for ensuring food security in the country) caused a sharp jump in prices, as well as a deficit in the first months of 2022. A similar situation was observed in the other mentioned above countries.

Changes in the global grain market have significantly complicated the logistics of Ukrainian grain exports. The blocking and shelling of logistics infrastructure facilities have led to a decline in the efficiency of Ukrainian grain logistics in the wartime environment. The main hypothesis of this study is that the disruptions to Ukrainian wheat exports caused by the war significantly increased the risks to food

security in low- and middle-income countries, changing traditional supply routes and increasing the vulnerability of commodity markets.

There is a need to develop mechanisms for grain exporters to adapt to the reconfiguration of grain export routes during the war in the context of a sharp drop in grain prices and rising logistics costs for its delivery to the places of consumption. This allowed us to formulate the objectives of this work:

- To conduct a study of the global grain market and establish the specifics of the economic conjuncture in terms of Ukrainian grain exports by the parameters of its evaluation.
- To analyze the concentration of the global grain market based on a quantitative assessment of the levels of competition at the stage of grain production.
- To formulate the directions of adaptation of the entities operating in the grain market of Ukraine, to ensure the safe operation and restore operational efficiency of logistics supply chains for grain exports during times of war.

A new reality is emerging in the world, according to which environmental disturbances have a dominant impact on the development of globalization processes. Disturbances, as well as global competition, significantly complicate the functioning of the economies of many countries and require the development of adaptation tools (in particular, in terms of unlawful monopolization of markets by counterparties, non-compliance with the security of flow processes, etc). In the context of radical uncertainty and growing instability in global development trends, it is of particular relevance to identify factors that contribute to sustainable growth and competitiveness of national economies (Pobochenko *et al.*, 2023). One of these factors is an active foreign economic policy (in particular, in terms of the participation of agricultural enterprises in the export of grain products to foreign markets, despite the conditions of war).

Rising Russian attacks in the Black Sea and increasing risks to global trade in vital products have made it necessary to improve coordination among Ukrainian farmers, traders, and international stakeholders under the state's export security regime. These countries needing it for food have led to the need to strengthen the coordination of efforts of Ukrainian farmers, traders, and other international stakeholders in the context of the state's application of the export security regime for the period of martial law and the development of mechanisms to ensure the safe delivery of grain cargoes in times of war. The sharp price fluctuations in the grain market that occurred during the war have had negative consequences for food security in many countries (World Bank, 2023b). This requires the development of preventive measures to mitigate and prevent these impacts, which is becoming an urgent task for government policy. An example is the urgent need to extend the grain corridor, the forced

transformation of most grain export logistics chains, addressing the issues of tariff and non-tariff instruments for regulating export operations, etc. An essential issue in the process of studying the dynamics of grain exports during the war is to identify the impact of these instruments on the economics of export transportation.

2. Literature review

The dynamics of the global grain market are an indicator of global economic reforms in countries. It affects the welfare of individual countries and their food security. For export-oriented countries, grain exports serve to maintain a positive trade balance and reduce the risks of their foreign economic activity. Low-income countries with food deficits and food insecurity, as well as countries in need of external assistance for food production, according to FAO (2023e), as they are in dire need of grain supplies, are at increased risk of famine due to the war in Ukraine and disruptions in grain supplies. The implementation of the UN World Food Program to address the global food crisis in times of war urgently requires an assessment of the global grain market, as well as the formation of directions for secure supply chains for grain exports by export-oriented countries, including Ukraine.

The paper by Bentley *et al.* (2022) argues that after COVID-19 and in the period of climate change, measures to respond to the multilevel global food crisis have been proposed. These measures mitigate short-term food security risks, stabilize wheat supplies, and ensure the transition to long-term sustainability of the agri-food system.

The work of Kushnir *et al.* (2023) reveals the peculiarities of the logistics activities of the international trade environment and formulate an understanding of the structure and specifics of logistics support in international transportation. The authors propose directions for the development of logistics in the organization of international transportation in wartime and determine the relationship of the main components of logistics with each other. The work of Rudyk *et al.* (2023) studied alternatives for the delivery of grain to storage and sales locations, taking into account the growth in grain transportation volumes and the state of the logistics infrastructure. The results of this study indicate the need to optimize Ukraine's transport infrastructure to ensure the growth of agricultural exports.

The scientific work of Afanasieva *et al.* (2023) is devoted to the marketing analysis of the activities of Ukrainian agro-industrial enterprises during the war, and the factors and risks that affect the efficiency of their functioning. A significant number of stakeholders of different institutional affiliations are interested in studying the global and Ukrainian grain markets in terms of optimizing the efficiency of logistics supply chains for grain exports from Ukraine. For example,

- The Ministry of Foreign Affairs of Ukraine and the European Commission - in the implementation of the Solidarity Roads corridors between Ukraine and

the EU, namely, to jointly develop the Danube cluster, as well as the Adriatic and Baltic transport corridors.

- The World Bank (2022) and the European Bank for Reconstruction and Development (EBRD, 2024) are in the process of restoring Ukrainian agricultural exports (CEE Bankwatch Network & Center for Environmental Initiatives Ecoaction, 2023).
- The Food and Agriculture Organization of the United Nations, FAO - in identifying the impact of the Ukraine-Russia conflict on global food security and developing the FAO Rapid Response Plan, to meet critical production and harvesting deadlines, access to food for vulnerable groups in Ukraine, and the development of logistics infrastructure in terms of grain storage and transshipment (FAO, 2022; 2023a; 2023b; 2023d).
- Scientific institutions: National Scientific Center "Institute of Agrarian Economics" – in the process of analyzing the food security of Ukraine in the conditions of war and the directions of post-war agricultural reconstruction. Polski Instytut Spraw Międzynarodowych PISM – in the process of identifying ways to end the sea blockade.
- Associations: The All-Ukrainian Association of Communities, supported by the USAID Agricultural and Rural Development Program (AGRO), studied the role of transport and logistics clusters/logistics hubs in ensuring food security in certain territories in the context of war. Ukrainian Grain Association, which represents the interests of the largest grain exporters. The European Business Association - in particular, when appealing to the UN to unblock seaports on the Black Sea.

In study, Hellegers (2022) highlighted the impact of disrupted wheat supply chains from Ukraine to low- and middle-income countries, particularly indicated the high level of food shortage that countries faced at the start of 2022, the sharp increases in food prices, and the challenges in establishing new grain supply routes. Egypt, the world's largest wheat importer, and Lebanon which heavily depends on Ukrainian grain, faced a significant challenge in maintaining food price stability. In 2022, Egypt reported record inflation in food commodities, with wheat prices alone rising by up to 44 %.

Despite the diversity of the studies conducted, the issues of determining the main competitive forces for dominance in the production of the core of the world wheat market remain insufficiently covered. Identification of the specifics of the Ukrainian grain market transformation and its participation in the world grain market in times of war has not been researched enough. The level of justification the peculiarities of logistical support for the further development of the Ukrainian grain market in the context of a sharp change in the world grain market conditions during the

disturbances were not enough researched. Particular attention should be paid to issues related to the development of a balanced state policy on the application of tariff and non-tariff methods of export regulation with the involvement of stakeholders of the international community to ensure global food security with the participation of Ukraine. Guided by the above, we will try to reveal the specifics of the factors influencing the situation in the Ukrainian grain market and its logistics in the system of global food security during the war in Ukraine.

3. Research methodology

To achieve the purpose of the study, a set of scientific methods was used to ensure the conceptual integrity of the study, in particular:

- Comparative and statistical analysis of exports of Ukrainian grain cargoes for which the export security regime was introduced by the classification of goods used by the Customs of Ukraine (QDProffesional, 2023).
- Problem-oriented method - to identify the main problems of economic development of the global and Ukrainian grain market and to identify factors influencing them.
- Index method - to assess the levels of concentration in the production segment of the global wheat market. The methods used in the study included methods of scientific retrospective analysis.

In this research, the capacity of the global grain market is calculated using the formula:

$$M = V + (I - E) - (Wb - End) \quad [1]$$

Where:

M: The capacity of the global grain market, million tons;

V: Global grain production, million tons;

I; *E*: Volumes of grain imports and exports, million tons, respectively;

Wb: World carry-over balances at the beginning of the period;

End: World carry-over balances at the end of the period.

The work calculates the capacity of the global grain market, which in the period 2019/2020-2023/2024 (forecast) increased from 3,157.8 million tons to

3,271.7 million tons, respectively; the growth rate of the global wheat market in 2023-2024 compared to 2019-2020, which amounted to 1.036, was revealed.

In this study, the capacity of the global wheat market is calculated by the formula:

$$M = V + (I - E) + (In - En) - (Wp - End) \quad [2]$$

Where:

M: The capacity of the global wheat market, million tons;

V: Global wheat production, million tons;

I; *E*: Volumes of wheat imports and exports, million tons;

Wb: World carry-over stocks at the beginning of the period, million tons;

End: World carry-over stocks at the end of the period, million tons;

ln; *En*: Volumes of indirect imports and indirect exports of wheat, respectively (as part of other goods, which include flour), million, respectively.

The paper calculates the capacity of the global wheat market, taking into account the volume of indirect imports and indirect exports of wheat (in the form of flour). In the period 2019/2020 - 2023/2024 (forecast), it increased from 942.5 million tons to 989.9 million tons, respectively. The growth rate of the global wheat market capacity in 2023-2024 compared to 2019-2020 was found to be 1.050.

Absolute global grain market conditions are determined by the ratio of supply and demand and indicate the absolute gap in global grain market conditions (ΔK). The absolute global grain market conditions (absolute gap of the global grain market conditions, Cabs) are determined by the formula:

$$\Delta K = S - D \quad [3]$$

Where: *S*: supply; *D*: demand; ΔK : dynamics of the global grain market.

It was found that the absolute growth of the global grain market in 2019/2020 amounted to 838.9 million tons. In 2023/2024 (forecast) it was 871.76 million tons. The absolute growth of the global wheat market in 2019/2020 amounted to 287.8 million tons. In 2023/2024 (forecast) - 311.7 million tons, respectively.

Relative market conditions reflect the growth rate of the global grain market. The relative market conditions of the global grain market are calculated by the following formula:

$$Krl = \frac{(S - D)}{D} = Tpr \quad [4]$$

Where: *Krl*: relative market conditions; *Tpr*: the growth rate of the global grain market.

The following formula was used to determine the share of producing countries in global wheat production:

$$Pk = \frac{Di}{M} \quad [5]$$

Pk: The share of producing countries in global wheat production;

Di: The volume of wheat production in a particular producing country, million tons;

M: Capacity of the global wheat market, million tons.

The Herfindahl-Hirschman Index (Rhoades, 1993) was applied to assess the level of concentration of the global wheat market. This methodology is consistent with previous studies, such as Addis *et al.* (2019), which assessed wheat market structures in Ethiopia using the Herfindahl-Hirschman Index approach to measure the intensity of competition between producers. The World Bank (2022) regularly uses HHI indicators to monitor market concentration across countries and sectors, including agricultural products. The calculation of the Herfindahl-Hirschman Index was performed according to formula [6], which quantifies market concentration by summing the squares of market shares of all major producers:

$$HHI = \sum_{k=1}^n p_k^2 \quad [6]$$

Where: *pk*: is the share of the *k-th* country - producer in the global wheat market, %; *n* is the number of firms for which the index is calculated, units; *k* = 1, ..., *n*.

Note the following interpretation of the Herfindahl-Hirschman index:

- *HHI* < 1000 – the market is weakly concentrated (high competition).
- 1000 < *HHI* < 1800 – the market is moderately concentrated (medium competition).
- *HHI* > 1800 – the market is highly concentrated (low competition, threat of monopolization).

The study calculated the values of the Herfindahl-Hirschman Index (for the ten-leading wheat-producing countries) for the global wheat market in 2021/ 2022 and 2022/ 2023 (717.99 and 709.87, respectively), which indicates that the global wheat market is weakly concentrated ($HHI < 1000$, high competition).

An alternative to the Herfindahl-Hirschman index is the market concentration ratio, which is calculated using the formula:

$$Mc = \sum_{k=1}^n p_k \quad [7]$$

Where: Mc : is the market concentration ratio.

If the value of this coefficient is close to 100 %, the global wheat market will be characterized by a high level of monopolization; if the index is close to zero, the global wheat market will be considered competitive.

The study calculated the Market Concentration Index of the global wheat market producers for the three leading countries (China, India, and the Russian Federation), which in 2021-2022 and 2022-2023 amounted to 41.33 % and 41.61 %, respectively. This indicates that the analyzed wheat market is not concentrated. It is worth noting that the share of each country among the top three producers is close to or above 10 %.

The market concentration indicator for ten countries with a share of more than 2 % in 2021-2022 was 68.99 %, and in 2022-2023 68.87 %, which confirms that the wheat market under study (when examining the ten-leading wheat-producing countries) is not concentrated.

To determine the number of wheat-producing countries that dominate the global wheat market (the limits of oligopoly) the Linda index was calculated (Linda, 1976). This index is used to identify the leading companies in the global wheat market and to track the emergence of monopolies. The use of the Linda index to determine the differences in the “core” of the global wheat market allows us to identify the number of companies that occupy a dominant position in this market. The Linda Index is calculated until the continuity of the growth or decline of the function under study is broken. This break in continuity will indicate that the contribution of the wheat-producing country added to the calculation is insignificant. The application of the Linda Index in this study follows earlier empirical uses by Ukav (2017), who investigated market structures in small economies, and Bukvić *et al.* (2014), who studied concentration tendencies within Serbia’s food industry.

The Linda index for two producing countries is determined by the formula [4; 14]:

$$IL2 = \frac{p1}{p2} \cdot 100 \% \quad [8]$$

Where: $IL2$: is the Linda index for two producing countries in the global wheat market; $p1$ is the market share of the leader in the global wheat market; $p2$ is the market share of the country of the next producer, in descending order, %.

The Linda index for the three producing countries and the global wheat market is determined by the following formula:

$$IL3 = \frac{1}{2} \cdot \left(\frac{p1}{\frac{p2 + p3}{2}} + \frac{\frac{p1 + p2}{2}}{p3} \right) \quad [9]$$

The Linda index for the four producing countries and the global wheat market is determined by the following formula:

$$IL4 = \frac{1}{3} \cdot \left(\frac{p1}{\frac{p2 + p3 + p4}{3}} + \frac{\frac{p1 + p2}{2}}{\frac{p3 + p4}{2}} + \frac{\frac{p1 + p2 + p3}{3}}{p4} \right) \quad [10]$$

The index is calculated until $L_{m+1} > L_m$, which is called “breaking the continuity of L ” meaning that the producer country’s share in the calculation is small in the producer countries and the global wheat market.

The paper calculates the Linda Index taking into account the shares of ten producing countries in the global wheat market. The interpretation of the value of the Linda Index revealed the continuity of the function in 2021-2022 and 2022-2023 for five countries - leaders of the global wheat market, which form a stable core of the global wheat market: China, India, and Russia. USA and Australia, indicating the nature of the countries’ behavior inherent in this market situation.

To determine the degree of unevenness in the distribution of wheat production among countries, the Gini index was calculated. It measures the extent to which the actual distribution deviates from a perfectly equal distribution. The Gini coefficient, originally developed by Gini (1912) and later extensively applied in studies of economic inequality (Sen, 1973), was employed to assess market share disparities. As the Gini value approaches unity, the concentration of wheat production among fewer countries becomes more pronounced. The Gini method aligns with previous agricultural market studies, such as Taru & Lawal (2012), who analyzed market concentration in Nigeria’s yam market, and Sterie *et al.* (2022), who assessed import and export concentration in Romania’s wheat trade.

The Gini index is calculated using the formula:

$$G = 1 - 2X \sum_{i=1}^n x_i Xcumy_i + \sum_{i=1}^n x_i Xy_i \quad [11]$$

Where: G is the Gini index; x_i is the share of the i -th wheat-producing country in the total; y_i is the share of the i -th wheat-producing country in the analysis of the global wheat market capacity structure.

The higher the Gini index, the more uneven the distribution of market shares between counterparties, and thus the higher the level of concentration of the global wheat market. The calculation of the Gini index for the global wheat market in 2021-2022 and 2022-2023 (which was 0.362 and 0.366, respectively) allowed us to characterize the global wheat market as a market with low uneven distribution of market shares between the top ten wheat-producing countries.

The study hypothesizes that external environment perturbations have led to a deterioration in the global grain market and affected the efficiency of Ukrainian export supply chains, which, in the face of rising military risks, force the adaptation of productivity growth strategies towards a strategy of minimizing costs - logistics, transaction costs, etc.

4. Results

4.1. Study of the dynamics of the global grain market

All sorts of perturbations (dominated by the pandemic response in 2020 and the war in Ukraine starting in 2022) significantly affect the global grain market, affecting the capacity of the global grain market, its absolute and relative conditions, food security of several food-insecure countries, etc. (Table 1).

The analysis of the dynamics of the global grain market in 2019/2020 - 2023/2024 showed a potential increase in grain production by 3.87 % and wheat production by 3.16 %. The supply on the global grain market, taking into account the initial stocks, in 2023/2024 will amount to 3,677.1 million tons, or 103.58 % of 2019/2020, and wheat – by 5.84 %. Demand in the period of 2019/2020 - 2023/2024 will increase by 3.47 % on the global grain market and by 4.89 % on the global wheat market. This will increase exports in the global grain market. In particular, in 2023/2024, the global trade in grains is expected to reach 472.7 million tons (or 7.53 % more than in 2019/2020) and 195.3 million tons of wheat (or 6.26 % more than in 2019/2020). The global population growth remains one of the key drivers of the demand growth for grains.

TABLE 1
Analysis of the global grain market dynamics in 2019/2020 - 2023/2024, million tons

Marketing year	2019/2020		2020/2021		2021/2022		2022/2023		2023/2024 (forecast)		2023/2024- 2019/2020	
	Grain	Incl. wheat	Grain	Incl. wheat	Grain	Incl. wheat	Grain	Incl. wheat	Grain	Incl. wheat	Grain	Incl. wheat
Production	2,713.9	759.3	2,778.5	775.3	2,815.0	778.3	2,788.7	801.8	2,819.0	783.3	1.0	1.0
Supply (production + initial inventory)	3,550.1	1,034.0	3,610.4	1,061.4	3,654.4	1,072.9	3,654.9	1,096.7	3,677.1	1,094.4	1.0	1.1
Demand	2,711.2	746.2	2,760.6	761.6	2,802.6	775.3	2,779.2	780.5	2,805.3	782.7	1.0	1.1
Trade	439.6	183.8	482.2	189.4	482.8	195.9	477.0	202.2	472.7	195.3	1.1	1.1
Inventories at the end of the period	831.9	286.1	839.4	294.6	857.3	294.9	858.6	311.1	878.1	313.9	1.1	1.1
Inventory utilization, %	30.1	37.6	30.0	38.0	30.8	37.8	30.6	39.7	30.6	39.5	0.5*	1.9*
Global Inventory-to-Consumption Ratio Index, %	18.6	15.6	18.4	15.2	19.2	16.0	20.4	19.0	21.2	18.6	1.1	1.2
Absolute market conditions	838.9	287.8	849.8	299.8	851.8	297.6	875.7	316.2	871.8	311.7	1.04	1.1
Relative market conditions	30.9	38.6	30.8	39.4	30.4	38.4	31.5	40.5	31.1	39.8	0.1*	1.3*
Market capacity	3,157.8	942.5	3,253.2	969.7	3,279.9	988.6	3,273.3	1,001.9	3,271.7	989.9	1.0	1.1

Note: * relative indicator.

Source: Author's own elaboration based on FAO (2023a; 2023b).

The analysis of the dynamics of the global grain market in 2019/2020 - 2023/2024 showed a potential increase in grain production by 3.87 % and wheat production by 3.16 %. The supply on the global grain market, taking into account the initial stocks, in 2023/2024 will amount to 3,677.1 million tons, or 103.58 % of 2019/2020, and wheat - by 5.84 %. Demand in the period of 2019/2020 - 2023/2024 will increase by 3.47 % on the global grain market and by 4.89 % on the global wheat market. This will increase exports in the global grain market. In particular, in 2023/2024, the global trade in grains is expected to reach 472.7 million tons (or 7.53 % more than in 2019/2020) and 195.3 million tons of wheat (or 6.26 % more than in 2019/2020). The global population growth remains one of the key drivers of the demand growth for grains.

The author notes that the economic situation in the global grain market is determined by the fierce competition of producing countries for dominance in the segment of wheat exports. In this paper, wheat is taken as a reference product in assessing the global grain market conditions in the context of grain-producing countries (Table 2).

According to the results of the global wheat market analysis, among the top 3 wheat producing countries, China, India and Russia take first 3 positions in wheat production with shares of 17.174 %, 12.971 % and 11.474 % respectively (as of 2022/2023). The top ten countries are followed by Ukraine with a share in the global wheat market of 2.09 % (2022-2023).

TABLE 2

Analysis of the production dynamics of the main countries - producers of the global wheat market in 2021 - 2022 - 2022/ 2023, million Tons

Country	Production		Share in global production, %	
	2022-2023	2021-2022	2022-2023	2021-2022
China	137.70	136.90	17.17	17.60
India	104.00	109.59	12.97	14.08
Russia	92.00	75.16	11.47	9.66
USA	44.90	44.79	5.60	5.75
Australia	39.00	36.30	4.86	4.66
France	35.00	36.99	4.36	4.75
Canada	33.80	21.65	4.22	2.78
Pakistan	26.40	27.46	3.30	3.53
Germany	22.60	22.10	2.82	2.84
Ukraine	21.00	33.01	2.10	3.34

Source: Author's own elaboration based on data Pohorielova (2024) and FAO (2023a; 2023b).

4.2. Assessment of global wheat market concentration

Increased concentration of competition in the global wheat market caused by the war in Ukraine and the possibility of redistribution of shares of the world's wheat leaders actualizes the assessment of the global wheat market concentration during the active phase of the war in Ukraine (Table 3).

TABLE 3
Analysis of the changes in the Herfindahl-Hirschman Index
in the period 2021-2022 and 2022-2023

Country	2021-2022		2022-2023		Share, 2022-2023/ 2021-2022
	Share, %	Herfindahl- Hirschman index	Share, %	Herfindahl- Hirschman index	
China	17.6	309.62	17.174	294.95	-0.422
India	14.08	198.25	12.971	168.25	-1.1091
Russian	9.66	93.26	11.474	131.65	1.817
USA	5.76	33.12	5.60	31.36	-0.155
Australia	4.66	21.75	4.864	23.66	0.2
France	4.75	22.59	4.365	19.05	-0.388
Canada	2.78	7.74	4.216	17.77	1.434
Pakistan	3.53	12.45	3.293	10.84	-0.235
Germany	2.84	8.066	2.819	7.947	-0.021
Ukraine	3.34	11.15	2.096	4.39	-1.2431
Total	-	717.99	-	709.88	-
Market concentration ratio	68.99	-	68.87	-	-

Source: Author's own elaboration.

Interpretation of the Herfindahl-Hirschman index for 2021/2022 and 2022/2023, the range of numerical values of which is [717.992 - 709.876]. It indicates that the global wheat market is weakly concentrated ($HHI < 1000$, high competition).

The market concentration of the global wheat market in 2021-FAO determining the dominant position of a particular country in the market under study, for three countries (China, India, and Russia). The share of each of them is close to or above 10 %, amounting to 41.33 %. In 2022 - 2023, this indicator amounted to 41.62 %, which indicates that the market under study is not concentrated.

The market concentration indicator for ten countries with a share of more than 2 % in 2021-2022 was 68.99 %, and in 2022-2023, it was 68.87 %.

The higher the value of this indicator for the same number of countries, the greater the market power of the largest countries. In addition, the higher the level of concentration on the global wheat market.

The results of calculating the Linda Index for the global wheat market are presented in Table 4.

TABLE 4

**Results of the Linda Index calculation for the global wheat market,
2021-2022 and 2022-2023, %, USD**

Linda index	Marketing year		
	2021-2022	2022-2023	2022-2023 / 2021-2022*
For two companies, IL2	124.97	132.40	7.43
For three companies, IL3	156.13	135.94	-20.19
For four companies, IL4	207.97	198.59	-9.38
For five companies, IL5	237.77	227.69	-10.08
For six companies, IL6	164.39	168.10	3.71

Note: * relative indicator.

Source: Author's own elaboration.

Thus, based on the results of the Linda Index analysis for 2021–2022 and 2022–2023, five leading countries –China, India, Russia, the United States, and Australia– form a stable core of the global wheat market. Mentioned countries indicate the nature of the countries' behavior inherent in this market situation. The detailed assessment of market differentiation and the Gini index for 2022-2023 is presented in Table 5.

Several factors determine the dominant position of certain countries in the world wheat market. These include favorable agro-climatic conditions that allow growing high-yielding varieties of wheat (for example, the United States and Australia); advanced agricultural technologies that increase productivity; government support, including subsidies and export promotion programs.

In addition, the United States and France have highly developed transport and port infrastructure that ensures efficient logistics and minimizes transportation costs. Political stability further strengthens their reliability as suppliers in world trade. It is also worth noting the role of the balance between domestic production and consumption. Countries with low levels of consumption have the potential to direct significant volumes of production for export. Such countries include Australia and Canada.

The listed factors are decisive in the process of forming dominant positions in the world grain market. The stability factor is especially important in the face of global cataclysms, military conflicts, and disruptions in supply chains.

TABLE 5

Calculation of the differentiation index and Gini coefficient in the global wheat market in 2022-2023

Country	y_i	y_i'	x_i	Differentiation indicator, y_i' / x_i	$\Sigma(x_i)$	$\Sigma(y_i)$	$x_i \times y_i$	$x_i \times \Sigma(y_i)$
Canada	2.096	0.0304	0.1	0.304	0.1	0.0304	0.00304	0.00304
Germany	2.819	0.0409	0.1	0.409	0.2	0.0713	0.00409	0.00713
Ukraine	3.293	0.0478	0.1	0.478	0.3	0.1191	0.00478	0.01191
Pakistan	4.216	0.0613	0.1	0.613	0.4	0.1804	0.00613	0.01804
Australia	4.365	0.0635	0.1	0.635	0.5	0.2439	0.00635	0.02439
France	4.864	0.0707	0.1	0.707	0.6	0.3146	0.00707	0.03146
USA	5.6	0.0814	0.1	0.814	0.7	0.396	0.00814	0.03960
Russia	11.474	0.1666	0.1	1.666	0.8	0.5626	0.01666	0.05626
India	12.971	0.1883	0.1	1.883	0.9	0.7509	0.01883	0.07509
China	17.174	0.2491	0.1	2.491	1.0	1.0000	0.02491	0.10000
Total	68.872	1.0	-	-	-	-	0.1	0.36692

Source: Author's own elaboration.

Using the intermediate totals reported in Table 5, Eq. [11] is evaluated as follows: $\sum_{i=1}^n x_i cum y_i = 0,36692$ and $\sum_{i=1}^n x_i y_i = 0.10000$ Substituting these values into Eq. [11] yields:

$$G = 1 - 2 \cdot 0.36692 + 0.10000 = 0 \tag{12}$$

Therefore, the Gini index for the global wheat market in 2022-2023 equals $G = 0.366161$.

According to the results of the calculation of the dynamics of changes in the Gini index, there is a slight increase in the value of the Gini index in the global wheat market in 2022-2023 compared to 2021-2022. The obtained estimate of the Gini index characterizes the global wheat market as a market with low uneven distribution of market shares between the top ten wheat-producing countries.

According to the analysis of the core of the global wheat market and the specifics of the activities of the leading wheat-producing countries, it was found that the analyzed countries quickly adapt to changes in market conditions. Due to the impact

of environmental disturbances, they are trying to increase their share of the global grain market by creating niches that have arisen because of transformation/blocking/narrowing/shortening of logistics supply chains for grain exports from Ukraine.

4.3. Analysis of the factors affecting the formation of the global grain market for the needs of global food security

A detailed qualitative analysis of the specifics of the global grain market allowed us to identify the following specifics of the dominant factors influencing the formation of the analyzed market conditions:

- The high level of development of the global grain market in 2019/2020-2023/2024 allowed creation of preconditions for meeting the needs for grain. Including wheat, not only the domestic needs of export-oriented countries but also countries that need external assistance for food production and low-income and food-deficit countries (LIFDCs).
- It is argued that the growing uncertainties caused by environmental perturbations create preconditions for fluctuations in the global grain market. Under stable conditions of the global grain market, price growth or high price levels, according to the laws of supply and demand, contribute to the growth of production volumes. However, environmental disturbances, such as the global pandemic, extreme weather conditions, and the ongoing rise in input prices, counteract the stabilization of the global grain market in 2020-2023 and affect global food security.
- The rise in grain prices on world markets has led agricultural producers to increase their sown areas, and the rise in global energy prices has led to an increase in the share of grain (mainly corn) used in biofuel production, which helps to maintain high prices.
- The war in Ukraine, which is accompanied by shelling of Ukrainian port infrastructure and superstructures in connection with the opposition to the Grain Corridor. It hurts the global grain market in terms of increasing the cost of insurance for export cargoes, including grain, by insurance companies in the Azov-Black Sea region.
- Rising prices in the energy market led to higher prices for fuel and electricity. Consequently, it affects the growth of prices in related markets, such as the fertilizer market, the market for plant protection products, etc., affects the cost of grain production upward and puts pressure on the reduction of grain production. Taken together, this could lead to a decline in production and exports by some export-oriented countries, including Ukraine. This will lead to an increase in grain carryover stocks. As a result, supply in the global

grain market will exceed demand and put pressure on global grain prices (Rabbi *et al.*, 2023).

TABLE 6

Types of disturbances on the example of some countries in the world that need external assistance for food production, as of July 2023

Types of disturbances	Country	Disturbances details
A. Exceptional deficit in aggregate food production/supply	Central African Republic, Yemen	Conflict, high food prices, extreme weather conditions
	Somalia, Chad	Drought conditions, civil instability
	Nigeria, South Sudan, Liberia, Lesotho	Economic decline, floods, civil instability
	Mozambique	Security
	Syrian Arab Republic	Civil conflict, economic crisis
B. Severe localized food shortages	Burkina Faso, Cameroon, Guinea, Lesotho	Civil instability, high food prices
	Congo	Refugee influx, floods
	Libya, Mali	Civil, economic, political instability, high food prices
	Madagascar, Uganda	Extreme weather conditions, slow economic recovery
	Afghanistan	Conflict, migration, economic downturn

Source: Author’s own elaboration based on data from FAO (2023e).

4.4. Identification of the place of the Ukrainian grain market in the system of global food security

Until the full-scale Russian invasion in February 2022, Ukraine played a significant role in global food security, being one of the world’s leading wheat exporters. In 2021, Ukraine ranked fifth among the world’s largest wheat exporters, accounting for approximately 10 % of global wheat exports and playing a significant role in ensuring food security in low – and middle-income countries, especially in Africa, the Middle East and Southeast Asia. It makes a significant contribution to global grain exports and is a guarantor of food security for countries in Africa, the Middle East and Asia (Kushnir & Anoshina, 2024). The range of variation in grain production in Ukraine in 2013-2022 amounted to 21.24 thousand tons due to a sharp drop in production during the war.

It is worth noting that during the war shock –2022–, global grain quotations on Euronext, France (the European trading platform chosen as the standard for comparing grain quotations), were at the level of 420-440 euros per ton. This allowed farmers to pay a high price for freight to avoid security risks of loss/removal/damage of cargo. However, in 2023, despite the termination of the grain agreement, the rate of the futures contract for wheat delivery in September 2023 was 233 - 236 euros/ton (as of July 18, 2023). This changed the approach to the formation of the grain export to the logistics economy: with the expectation of growing grain market conditions, building optimal logistics routes rather than focusing on the spot; taking into account the deadweight of the vessel being loaded for export.

The war has sharply reduced Ukraine’s agricultural production and especially its export capabilities, as exports were carried out precisely through seaports that were partially occupied, blocked or frequently shelled by Russia. In 2022-2023, Ukraine’s share of global wheat production fell to 2.09 % (FAO, 2023a), with a significant decrease in export volumes (Table 7). The suspension of the Black Sea Grain Initiative for a certain period has brought uncertainty to Ukraine’s future ability to export grain. However, thanks to successful military operations, Ukraine has ensured the stability of its ports and grain supplies to key partners.

TABLE 7

Ukraine’s role in the global wheat market, prior to and during the war

	Before the War (2021)	After the Start of the War (2022-2023)
Global Wheat Export Ranking	5 th largest exporter	8 th –9 th position (depending on year and source)
Share of Global Wheat Exports	~10 %	~5-6 %
Share of Global Wheat Production	~3.5 %	~2.09 %
Annual Wheat Exports	~20 million tons	~10-12 million tons
Export Logistics	Primarily via Black Sea ports (Odesa, Chornomorsk, Pivdennyi)	Overland through Solidarity Lanes, river ports on the Danube, Odesa port)
Main Challenges	Seasonal variability	Infrastructure destruction, port blockades, security risks, increased logistic costs

Source: Data compiled based on FAO reports (FAO, 2023a, 2023b; 2023c; 2023d; 2023e), Ministry of Agrarian Policy and Food of Ukraine (2023), and World Bank (2023a).

Despite this, Ukraine has still lost its position on the international market, and the continuation of military operations, constant shelling of infrastructure, and grain blockades by neighboring countries significantly affect Ukraine’s ability to restore its

global export positions (Neyter *et al.*, 2024). And as a result, they significantly affect global food security.

In 2021, before the full-scale war, Ukraine harvested a record 32.2 million metric tons of wheat, providing a significant share of global wheat production. However, following the Russian invasion, wheat production fell sharply to around 20.5 million tons in 2022, 36 % below pre-war levels.

The decline was driven primarily by the occupation of key agricultural regions, extensive destruction of agricultural infrastructure, labor shortages, and limited access to fertilizers and seeds. Despite ongoing initiatives and stabilization of the front, wheat production in 2023 remained low at around 21.0 million tons, reflecting the ongoing challenges facing Ukrainian agriculture in wartime conditions.

The disruption of Ukrainian grain exports following the Russian invasion in February 2022 has had a significant destabilizing impact on food inflation rates worldwide, particularly in countries that were significant importers of grain from Ukraine until 2022 (OECD, 2023). According to an analysis of food inflation rates from December 2021 to December 2024 in Somalia, Tunisia, Laos, Pakistan, and Egypt, there has been a sharp upward trend since the start of the full-scale Russian invasion of Ukraine (Figure 1).

In the first months after the start of the full-scale war, food inflation increased sharply, especially in Somalia and Pakistan, where domestic markets are heavily dependent on imported grain. The implementation of the Solidarity Belt Land Transport Initiative in May 2022 and the conclusion of the Black Sea Grain Initiative agreement in July 2022 contributed to a temporary stabilization and even a slight decrease in food inflation worldwide and in particular in the mentioned countries. However, after Russia's withdrawal from the Black Sea Grain Initiative in July 2023, inflationary pressures intensified again, which exacerbated supply disruptions and increased transport costs for a certain period. However, since October 2023, thanks to the Ukrainian Armed Forces, it has been possible to ensure the stable operation of some Ukrainian ports and ensure the supply of grain to key partner countries.

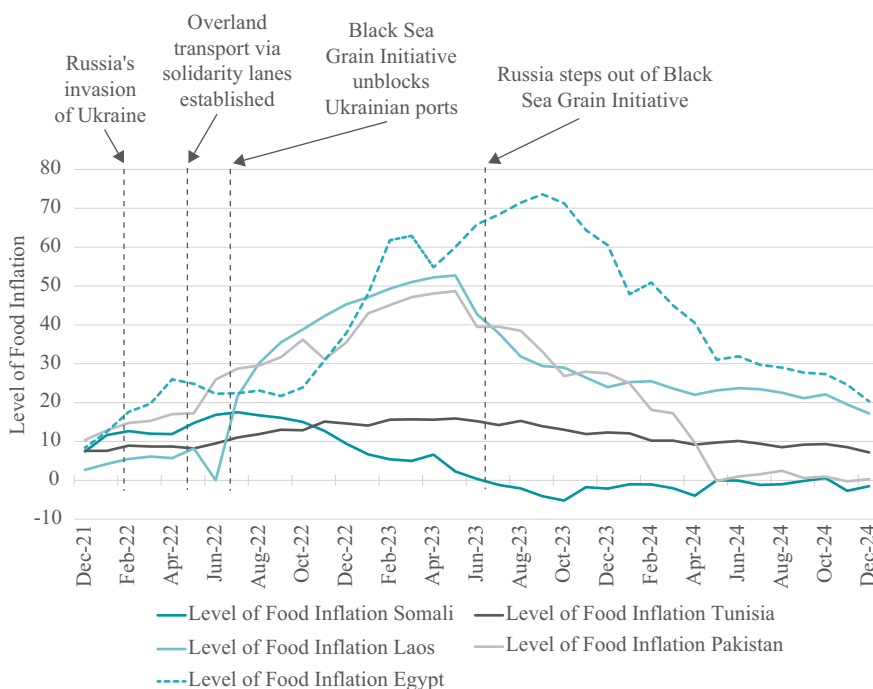
The data shows that Somalia has experienced the greatest volatility, with food inflation peaking at over 40 % during periods of export blockades. Tunisia and Egypt also recorded significant food price inflation, highlighting the sensitivity of North African markets to disruptions in Black Sea grain flows. In Laos and Pakistan, persistent inflation has eroded household purchasing power, undermining living standards and deepening poverty, particularly among the low-income population.

The results of this analysis highlight the direct link between the Russian-instigated war in Ukraine, the functioning of global grain supply chains, and the economic vulnerability of import-dependent countries. The analysis confirms that initiatives that facilitated Ukrainian grain exports had a mitigating effect on food price inflation,

and subsequent gains by the Ukrainian military, as well as the establishment of alternative supply chains, have further reduced inflation in the countries under consideration.

FIGURE 1

Monthly food inflation rates in Somalia, Tunisia, Laos, Pakistan, and Egypt, highlighting the impact of the Russian invasion of Ukraine and major export initiatives



Source: Author's own elaboration based on food inflation time-series data from Trading Economics (2025a; 2025b; 2025c; 2025d; 2025e), which reports national statistical offices as the original data sources: the Central Agency for Public Mobilization and Statistics (CAPMAS), the Lao Statistics Bureau, the Pakistan Bureau of Statistics, the Somali National Bureau of Statistics and the National Institute of Statistics of Tunisia.

The structure of export cargo transportation has undergone a significant transformation due to security risks. There are alternative methods available to export Ukrainian grain, which are:

- Sea transportation involving the deep-water ports of the Odesa region, through which grain crops were exported by large bulk carriers.
- Transit supplies of grain through Ukraine's land border.

- River transportation on the Danube. It is considered the most difficult logistical route given the risks of contract fulfilment, but it is the most promising in terms of the unit cost of cargo transportation.

Russia's blockade of seaports forced the reformatting of logistics routes for grain exports towards the western land corridor through EU ports: Romanian, Polish and Baltic. Taking into account security risks helped to increase grain exports to the EU by 65 % in 2022. In particular, excluding transit, grain exports to Poland increased by 38 %, to Hungary by 54 %, to Slovakia by 575 %, and to Romania by 690 % (Hordiychuk, 2023)

The de-occupation of Zmiinyi Island, despite the blockade of seaports, allowed to use of the potential of the Danube ports and triple the passage of ships from nine to twelve units per day (or 90 thousand tons per day), which is about 10 million tons of additional cargo per year (or an additional USD 1.5 billion). Increasing the draft of vessels from 3.9 m to 6.5 m has created additional potential for grain exports through this export channel.

With the introduction of the "Grain Corridor", grain transportation through it became dominant (53.5 %) in the structure of grain transportation –March 2023–, or 3.77 million tons compared to March 2022; river transportation increased to 28.7 % (or 2.022 million tons) against 16.6 % (or 0.055 million tons) –March 2022–; rail transportation in the structure of transportation amounted to only 15.2 % (or 1.075 million tons) –March 2023–. –March 2023– against 76.44 % (or 0.253 million tons) in March 2022. It should be noted that there was a significant increase in the intensity of involvement of all types of transport in Eastern Europe in March 2022 - March 2023: river - 36.76; rail - 4.29; road - 7.95; the volume of transportation through the "Grain Corridor" amounted to 3.77 million tons, which totaled 21.29 (Table 8).

The instability and war in Ukraine have a significant impact on the economic efficiency of grain export, supply chains and export pricing (Teixeira da Silva *et al.*, 2023). High risks of shipping Ukrainian grains by sea and, as a result, high freight rates have led to a decline in grain purchase prices. The saturation of the grain market in Europe is leading to a decline in export prices, in particular for milling and feed wheat exported by land. The mismatch between transshipment capacities and available storage capacities in the ports of Spain, Italy, and Turkey restrains existing logistics grain flows awaiting transshipment and the arrival of new logistics flows. The market saturation with wheat in 2022/2023 is typical for all European markets.

The price situation on the grain market was driven by a decline in exports by sea, which dominates grain exports, amid the termination of the grain agreement. As a result, there was an increase in demand for overland transportation, which contributed to queues at western border crossings. The low percentage of grain transportation

plans agreed with Ukrzaliznytsia, shippers, and foreign carriers expanded the list of bottlenecks in overland grain transportation. For example, unfavorable weather conditions in southern Ukraine, which affected grain quality, as well as the security situation in the region, are forcing farmers to refrain from holding large grain stocks and putting downward pressure on export prices to speed up grain sales. Rising railroad transportation tariffs also complicate grain exports.

TABLE 8
Analysis of the Dynamics of Ukrainian Agricultural Exports to Eastern European Countries with the Involvement of the Grain Corridor: Short-Term Trend, million tons

Type of transportation	Mar 2022	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan 2023	Feb	Mar	Mar 2023 / Mar 2022
River	0.055	0.265	0.799	1.070	1.379	1.264	1.21	1.137	1.218	1.348	1.006	1.345	2.022	36.760
Railway	0.253	0.602	0.710	0.747	0.932	0.955	1.030	0.970	1.120	1.152	1.069	1.020	1.075	4.290
Automobile	0.023	0.091	0.212	0.323	0.417	0.624	0.640	0.639	0.677	0.480	0.423	0.465	0.183	7.950
Grain corridor	0.000	0.000	0.000	0.000	0.026	1.677	3.956	4.103	2.842	3.727	2.953	3.438	3.770	–
Total	0.331	0.958	1.721	2.140	2.754	4.520	6.836	6.849	5.857	6.707	5.451	6.268	7.050	21.290

Source: Author's own elaboration based on data from the Ukrainian Grain Association (2023) and Hordiychuk (2023).

Considering the tariff setting for grain transportation by river in the Danube ports, it should be noted that the dominant part of the fleet operates under long-term contracts. However, some shipowners (including the Ukrainian Danube Shipping Company) are present on the spot market, where non-contracted freight is offered for auction. Using Prozorro as a tool for determining the objective market freight rate, shipowners represent their interests at a particular time in a volatile market, where the Internet platform serves as an additional indicator for price formation (Table 9).

It should be noted that Russia’s attacks on port infrastructure facilities after the termination of the grain agreement significantly exacerbated military risks in shaping the short- and medium-term situation on the grain market. Therefore, the predictability of logistics, the absence of bottlenecks and force majeure (downtime, attacks on grain and logistics infrastructure, etc.) in the logistics economy become crucial criteria for the structure and configuration of logistics chains and are reflected in the short-term grain freight rates (Table 10).

TABLE 9

**Comparative analysis of market rates for the transportation of grain crops
by type of transport, august 2023**

Type of transportation		Market rates, €/ton	Pricing trend
Motor vehicle transportation	West. Ukraine - n. Italy	105-115	Interest rates remain low due to the small number of trades
	Center. Ukraine - south Romania	70-80	Growth in cargo transportation volumes drives rate increases
	West. Ukraine - e. Germany	110-120	Active fulfilment of rapeseed export contracts, with a limited number of dump trucks on the market, led to an increase in rates
	Internal transportation	-	No significant changes in interest rates.
Railway transportation	Center of Ukraine - Hungarian border	21-24	Regulated rates by “Ukrakaliznytsia”
	Center of Ukraine - Izmail	22-25	Delivery of more than 2600 grain wagons per 100 tons/day (estimated waiting time for unloading is 26 days) is carried out under the conditions of transportation tariffs regulation by the monopolist “Ukrakaliznytsia”
	Ukraine’s border with eastern Germany	64-66	Growth in demand for rail deliveries to European customers with a shortage of European railcars leads to an increase in transportation rates
	Ukraine’s border - northern Italy	60-62	Growth in demand for rail deliveries to European customers with a shortage of euro cars among European carriers leads to an increase in transportation rates
	Internal transportation	-	No significant changes in interest rates.
Water transportation	Sea transportation	-	Projects of maritime corridors for grain transportation without Russian participation in the territorial waters of Romania and Bulgaria are limited due to insufficient depths and involve significant military risks, which increase the level of rates. However, per ton of cargo (unit cost), the rate level is the lowest compared to other modes of transportation
River transportation	Izmail, Ukraine - Constanta, Romania	40-45	Long-term vessel downtime in Romania makes it difficult to schedule vessels for loading, which affects freight rates from the region.
	Reni, Ukraine - Alexandria, Egypt	43-47	Increase in freight rates due to the limited number of vessels available for loading in ports.

Source: Author's own elaboration based on market-rate data from Spike Brokers analysts, as reported by Elevatorist.com (2023), Horoshkova *et al.* (2024), Kolisnichenko (2022).

TABLE 10

Impact of security risks on wheat freight rates by water transport from Ukraine

Direction	July 23, 2023	August 3, 2023	Growth rate
Eastern Mediterranean	43-45	50-52	1.16
The east coast of Greece	39-40	46-47	1.17
Crete	42-44	49-51	1.16
Israel	48-50	55-57	1.14
The east coast of Italy	50-52	53-55	1.06
Spain	56-58	58-60	1.04

Source: Author's own elaboration based on market-rate data from Spike Brokers analysts, as reported by Elevatorist.com (2023), Horoshkova et al. (2024), Kolisnichenko (2022).

The established medium-term grain export target requires appropriate logistics support. Examples of logistics and transport infrastructure projects within the framework of building a medium-term grain export strategy include:

- The Ukraine-Romania export corridor to expand alternative routes for grain exports by land, sea and river transport, including: increasing the throughput capacity of the port of Constanta through the Sulina Sea Canal from two million tons/month to four million tons/month (for a 50 % increase in the throughput capacity of the canal); improving the efficiency of the port of Galati, Romania; opening new border crossing points from Ukraine and increasing the number of staff at the existing border crossing points; providing equipment for border crossing points in northern Romania; maximizing the use of grain containers located in the port of Constanta; increasing the number of pilots on the Romanian Danube Sulina Canal in connection with the involvement of water transport to ensure greater cargo flows.
- The Ukraine-Romania (rail) - Bulgaria (rail) - Bulgaria-Greece (water) export corridor. The bottleneck of this route is the shortage of Bulgarian locomotives and wagons at the state carrier, as well as the shortage of rolling stock at Bulgarian private railroad companies. At the same time, Greece is building a railroad to Kulata and Svilengrad, which will eliminate bottlenecks in the existing transportation. The alternative of transshipment of Ukrainian barges in Romanian territorial waters, where grain cargoes can be transhipped to large vessels, is also being considered.
- The export corridor Ukraine - the Baltic States, Croatia, and Italy. In addition to the logistics leverage, which significantly increases the cost of cargo delivery, the bottlenecks of grain transportation by rail are the difference in track gauge in Ukraine and the EU.

5. Discussion and conclusions

This study presents the results of the analysis and assessment of the economic situation on the global grain market and the place of the Ukrainian grain market in it during the period of aggravation of the food crisis in a number of low- and middle-income countries as a result of the war in Ukraine.

The transformation of the global grain market required a study of the specifics and conditions of competition among the leading wheat exporting countries, based on quantitative indicators of market concentration and monopolization. The results of the analysis of the global grain market and the conclusions regarding price transformations and changes in the routes of transportation of Ukrainian grain in the conditions of war allowed us to outline the logistics support for the realization of the goals of exporting Ukrainian grain cargo.

The application of index methods for assessing the global grain market allowed identifying and assessing the core of the market under study, to analyze the distribution of “market power” by the country’s leading in grain production. Conclusions are drawn about the intensification of competition in the global grain market in the wheat sector during the war, which together lead to increased barriers to entry in the industry, and the displacement of competitors using tariff and non-tariff measures. In addition, the uncertainty caused by the hostilities in Ukraine during the “war shock” period, according to the authors, led to a significant increase in grain prices, stocks, and the cost of its delivery. Instead, in the post-peak period, the dominant factors of purchases in the global grain market are the cost of logistics and the market factor, due to sufficient global production to meet demand and the global transitional balances. It is noted that grain imports remain relevant for low- and middle-income countries.

As a factor in the adaptation of supply chains for Ukrainian grain exports during the war, one should consider the development of enterprises in related and tangential industries, whose development strategies provide for entry into the Ukrainian grain market. Increasing the efficiency of operational activities of participants in logistics chains (due to flexibility and high technological efficiency) and its logistics support (among other things, through the restoration of logistics infrastructure and supra-structure facilities, the transformation of grain transportation routes depending on security risks, etc).

The results of the study of the global grain market and the place of the Ukrainian grain market in it during the war will help to increase the adaptive capacity of the counterparties of the Ukrainian grain market to uncertainties, aggravation of competition and security risks, as well as to form competitive advantages due to the following proposed solutions:

- Comprehensive consideration of the factors influencing the global grain market conditions when adapting grain transportation routes to the impact of the war and restoring shipping routes among them.
- Providing offers on the global grain market based on a value-based approach: high value-added offers for middle- and high-income countries, low value-added offers for low- and middle-income countries; prevalence of high value-added goods in the total supply.
- Increasing the efficiency of operations.

The author argues that the results of the study on the adaptive behavior of counterparties of grain export supply chains during the period of disturbances can be applied to other countries and national systems to restore global food security. Under similar factors of disturbances, other countries or national systems for the purpose of sectoral restoration of global food security can apply them.

There is a trend to decrease of growth rates of the global economy, which according to the estimates of The Economist Intelligence Unit amounted to 2.8 % in 2022 in addition to the lower GDP growth amount compare to the world trade growth rate (Métivier *et al.*, 2023). Global grain supply chains in the context of overcoming the recession by economies of many countries, will respond with high price elasticity to the security of their escort (Zhang *et al.*, 2024; Wang *et al.*, 2024).

Sufficient global grain production in 2022/2023 to meet demand allows diversification of purchases to create stocks for consumption needs. Low- and middle-income importing countries will experience a decline in demand due to rising grain prices. For other groups of counterparties in the global grain market, such as the UN Global Food Program, which provided more than 80 % of wheat stocks in East Africa in 2023 amid significant military risks, it is becoming important to diversify grain purchases from other countries, outside Russia and Ukraine, where security risks are high, at higher prices.

In conditions of market uncertainty, the entry of new players (for example, Argentina) will be characterized by the need to transform the vector of development of the global grain market towards the dominance of the pressure of international institutions and geopolitical factors of influence in order to regulate the security risks of grain delivery. In terms of shaping the trajectory of global grain supply chains, security risks will remain a priority. In the context of further recession in the global economy, the strategy of “increasing productivity” at all links of the supply chain is transformed into the strategy of “reducing logistics/transaction and other costs”.

The results of the study confirm the proposed hypothesis. Disruptions in Ukrainian wheat exports, caused by active military operations, shelling of port infrastructure, blackouts, logistical and production problems of wartime significantly increased the

risks to food security in low- and middle-income countries. Quantitative analysis of supply chain transformations and market concentration indices confirmed the vulnerability of global commodity markets and the instability of traditional grain supply routes in conditions of military operations. Thus, the hypothesis of aggravation of food security and disruptions in supply chains due to the war in Ukraine is confirmed by empirical data and market trends.

For the Ukrainian grain production, the most typical financial risk is a significant decrease in the return on working capital of agricultural enterprises and significant logistics costs increase. In addition, Ukraine will continue facing with changes inside of grain export structure and decrease in concentration of market share at some typical for the country markets (Hamulczuk *et al.*, 2023).

For the needs of Ukrainian exports, it remains important to invest in the restoration (due to the destruction during the war) of high-tech logistics infrastructure for exports by waterways, and in grain production, given the direct losses of USD 6.6 billion, where the “5-7-9” lending program and the 2/3 compensation program remain relevant (Ahres *et al.*, 2023; Neyter *et al.*, 2024).

In addition, we should expect a reorientation of some grain export routes from low- and middle-income countries (due to significant security risks) to the EU. It should be based on the concepts of sustainable development, waste-free production, and high marginality of export products due to their significant benefit.

Authorship contribution

Nazar Fihun: Project administration, Resources, Data curation, Writing – review & editing. **Olena Shandrivska:** Conceptualization, Methodology, Investigation, Writing – original draft, Writing – review & editing. **Sylwia Nycz-Wojtan:** Methodology, Validation, Supervision, Writing – review & editing. **Viktor Krykavskyy:** Formal analysis, Investigation, Visualization, Writing – review & editing.

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