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Formation of the Food Supply System for the Population of Ukraine in the European Agricultural Market Environment

*Oksana V. Hryvkivska, Igor I. Vinichenko, Olesia A. Shypylina, Yurii V. Premudryi, Yurii S. Stepaniuk**

The article examines the conditions for the formation of the food supply system (hereinafter – FSS) of Ukraine in the European environment of the agrarian market. The conceptual foundations of the new paradigm of the FSS of the recipient country in the European environment of the agrarian market were developed and a system of criteria for the comprehensive evaluation of its integral indicator was presented. Indicators of food self-sufficiency were given, and a SWOT analysis of the food supply of the population in the recipient country was carried out. Indicators of the state of food security in Europe and the prevalence index of malnutrition in the world have been determined. Preventive security measures of the FSS of Ukraine (the recipient country) in the environment of the agricultural market of the European donor countries were developed. The decomposition of the general variation of the share of expenditure on food products in the structure of aggregate expenditure of households of Ukraine and European countries in the two-year forecast period was carried out.

I. Introduction

In today's worldview, instability and the potential for military conflicts are an integral part of the geopolitical landscape, and achieving food security for the population is an extremely important task for the state. Ukraine, as a sovereign country, faces numerous geopolitical challenges and instability in the modern world. Among such threats, a special place is occupied by military conflicts, which can significantly limit access to necessary resources, including food. In addition, in the conditions of a full-scale military invasion by the Russian Federation, Ukraine must also take into account another new challenge – the daily needs of a significantly increased army and mobilised people for high-quality and balanced nutrition.

This circumstance puts an additional burden on the state's obligation to ensure a state of security and safety in access to food resources in sufficient quantity for all its citizens, and also puts forward certain specific requirements for the army ration. The food of the army and the mobilised should be of high quality, balanced, not require any special conditions for its storage, have a sufficiently long shelf life, be quick and easy to prepare, and also, if necessary, satisfy special needs regarding specific, kosher and vegetarian food.

Despite the critical conditions of the state of agricultural production in Ukraine, due to the Russian invasion of the territory of the Eastern and Southern parts of the country, as well as the refusal to import energy carriers from the aggressor country, the agricultural market of Ukraine is an important pillar of the national economy, as it demonstrates the ability and stability to fulfill an important mission in the conditions of a military conflict – meeting the food needs of the population. Military operations, population displacement and destroyed infrastructure can

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significantly complicate the production, storage and supply of food.[1]

However, the agricultural market remains a powerful platform for quickly solving issues related to the use of the existing potential of agriculture with the use of organic production and partial processing of waste into alternative sources of energy and fertilisers in order to improve the quality of food products. The main global task of the agricultural market, as a system of institutions, methods and resources for the implementation of exchange processes, is the coordination and management of the country's agricultural production in order to meet the needs of the population for quality and organic products. Added to this are the challenges associated with climate change, which may affect the yield and quality of agricultural products. At the same time, providing high-quality and safe products is a key task for preserving the health of the population.[2]

The multifaceted, complex and, in many cases, the presence of contradictions to the solution of the problem of food supply of the population with food products continue to be debatable and disputes regarding its nature, economic essence and need an urgent solution. Scientists such as D. Tokarchuk, N. Pryshliak, S. Berezyuk and A. Shynkovych emphasise that food supply allows expanding the physical and economic accessibility of the population to products through state programs for the development of the agro-food complex, food logistics programs, the formation of strategic food stocks and providing food aid to a socially vulnerable society.[3] R. Mudrak and I. Nyzhnyk prove that food security, as a system of relationships between producers, sellers, consumers of food products, as well as state authorities with the provision of food to the needs of the population, sets quality standards in accordance with scientifically based norms, which provide for the responsibility of the authorities to the population for ensuring the physical and economic availability of food at all stages of the cyclical development of the social system.[4]

At the same time, M. Horlachuk considers food security either as an economic system, the basis of which is the solvent demand of the population for food, the necessary satisfaction of their physiological needs, or as a set of interdependent industries involved in the production of food, or as a system of measures for the state regulation of the processes of stable provision of food availability for the population with different income levels in the amount necessary for leading a healthy life, or as a set of tools used by the state to meet the population's food needs, or as an agro-food complex, including objects of market and social infrastructure.[5]

However, in the majority of studies by scientists, the food supply of the population and food security in the country is not considered in the European integration space as a food system of the agricultural market. They are interrelated, although their meanings and approaches differ. Food security and food security are interrelated because achieving food security requires effective food security, while food security becomes a mechanism for achieving food security.

In the context of the above, the priority of our research is to substantiate at the methodological level the transmission of the channels of the food supply system (FSS), which, on the basis of cognitive modeling, determines the cause-and-effect relationships between its formative components to regulate the production chains of high-quality food products between the country-recipient and the country-donor and implementation of strategic directions for their development in the European agricultural market environment.

II. Materials and Methods

The food security system (FSS) is developed by the state and is reduced to the creation of conditions for the development of the economic mechanism, control over the use of resources in agriculture, support and protection of the economic interests of producers, and the formation of food stocks and reserve funds.[6] The structure of the FSS, depending on the

1 Oksana Nikonenko, 'Methodological support for the formation of food security of Ukraine' (2022) 9-10 Agroworld 86.

2 Iryna Furman, Dina Tokarchuk, 'Food security and economic principles of biofuel production' (2018) 1 Economic Analysis 168.

3 Dina Tokarchuk, Natalia Pryshliak, Sergiy Berezyuk, Andrii Shynkovych, 'Food security and biofuel production: solving the dilemma on the example of Ukraine' (2022) 25 Policy Energy 179.

4 Ruslan Mudrak, Iryna Nyzhnyk, 'Development of rural areas and food security of the state' (2019) 94 Collection of Scientific Works of the Uman National University of Horticulture 131.

5 Mykola Horlachuk, 'Agricultural market in conditions of globalization: cyclical development, coexistence and food security' (2013) 2 University Scientific Notes 219.

6 Natalia V. Trusova, Ivan V. Svynous, Yurii Prus, Olesia Yu. Havryk, Andriy V. Ivanovskiy, 'Assessment of agricultural lands as the basis of Ukraine's food supply' (2023) 80 International Journal of Environmental Studies 334.

surrounding environment, is determined by complementarity, which has certain characteristic features of the interaction of subjects of certain branches of agriculture and food industry, subject to compliance with the organic properties of the functioning of rural areas, on the basis of the doctrine of food security and meeting the needs of the population in food products.

The approach of agricultural production to industrial production according to the characteristic methods of management requires significant changes in the results of development, science, technology and technology and their implementation in processes affecting food with the use of bioengineering, nanotechnology, inventions in mechanical engineering, information systems, etc. Therefore, there is a need for the formation of a fundamentally new paradigm for the safety of the FSS, taking into account the needs of the main types of food products. Accordingly, the new paradigm of the recipient country's agricultural and food policy for the future should form a qualitatively new system of strategic vectors of integration into the European agricultural market model (Table 1).[7]

The state of the FSS is determined by a set of parameters, criteria and indicators of physical and economic availability of food.[8] The system of criteria and indicators of FSS may include such indicators as: physiological norms of consumption per person; the structure of consumption, which is calculated from the demand of the solvent population and takes into account the actual consumption of self-produced products; nutrition level indicators, calculated as the ratio of the existing consumption structure to the total physiological need; indicator of self-sufficiency of the region in food products; indicators of the state of capabilities of the agro-food complex; producer's consumer basket – an indicator characterising production costs; production balance and product marketability coefficients.[9]

According to V. Kuzyoma, the quantitative assessment of food supply to the population can be assessed using two groups of indicators: the level and dynamics of consumption of basic food products, taking into account their differentiation by population groups with different incomes; the level of the country's food self-sufficiency, in particular, within the limits of basic food products.[10] D. Krylov offers a classification of quantitative assessment criteria, which is based on a methodical approach to monitoring in the field of ensuring food safety.[11] Such scientists as O. Khaietska and V. Loianich emphasise the importance of carrying out a quantitative assessment based on criteria based on absolute and relative indicators.[12]

A comprehensive assessment of the FSS of the country-recipient is possible with the help of an integral indicator that correlates the production of high-quality food products, the level and differentiation of the population's income, the ability of the agro-food complex to produce basic food products in sufficient quantities that meet the standards. The algorithm for calculating the index of the food supply system and its security in the recipient country has the following form:[13]

$$I_{fss}=((EA_{ii} + LEA_{in}) + (PA_{ii} + LPA_{in}) + (QFS_{ii} + LFS_{ii}) + ({}^{LA}cc_{ii} + {}^{LLA}cc_{ii} + (V_{is} + S_{is})/100 \quad (1)$$

where, I_{fss} – index of the FSS; EA_{ii} – indicator of economic availability; LEA_{in} – the weight of the indicator of economic availability; PA_{ii} – indicator of physical availability; LPA_{in} – the weight of the physical availability indicator; QFS_{ii} – quality and safety indicator; LFS_{ii} – the weight of the quality and safe-

7 Iryna Furman, Anna Revkova, Oleh Revkov, 'Directions for the formation of the food supply system for the population of Ukraine under martial law' (2023) (58) Economy and Society <https://economyandsociety.in.ua/index.php/journal/article/view/3317> accessed 21 October 2024; Tetiana Overkovska, 'Legal assurance of the quality of food products' (2023) 1 Legal Scientific Electronic Journal 224; Mariia Popovych, Anton Popovych, 'The essence of food security and its place in the structure of economic security of states' (2024) 75 Bulletin of the Lviv University of Trade and Economics 109; Ihor Rumyk, *Food Security of the State: Issues of Theory, Methodology, Practice* (KROK University of Economics and Law 2020); Svitlana Urba, Marta Kopytko, 'Strengthening food security as a tool for realizing the potential of competitive development of agricultural sector entities in the system of economic security of Ukraine' (2022) 5 Problems of Modern Transformations: Economics and Management 56.

8 Olena Nikoliuk, Halyna Atamas, Bohdan Shumilov, 'Food security of Ukraine in the conditions of socio-economic transformations' (2023) 15 Economics of the Food Industry 60.

9 Anastasiia Blagopoluchna, 'Economic availability of food in conditions of war' (2022) 3 Economic Horizons 13.

10 Vitalii Kuzyoma, 'Assessment of the current state of global food security' (2024) 191 Economic Space 417.

11 Denys Krylov, 'Problems of ensuring food security of Ukraine in modern conditions' (2023) 7 Problems of Modern Transformations: Economics and Management <https://reicst.com.ua/pmt/article/view/2023-7-03-07> accessed 12 October 2024.

12 Olha Khaietska, Volodymyr Loianich, 'Ensuring food security of Ukraine in war conditions' (2023) 6 Efficient Economy <https://nayka.com.ua/index.php/ee/article/view/1723> accessed 12 October 2024.

13 Furman, Revkova, Revkov (n 7); Ruslan Mudrak, Volodymyr Lagodienko, Alla Osipova, Oksana Frother, Kateryna Sokolyuk, 'Concept of food security: Theory and Ukrainian practice' (2024) 1 Financial and Credit Activity: Problems of Theory and Practice 452.

ty indicator; ${}^{LA}cc_{ii}$ – indicator of stability and adaptation to climate change; ${}^{LLA}cc_{ii}$ – the weight of the indicator of stability and adaptation to climate change; V_{is} – the weight of the consumption adequacy indicator; S_{is} – average indicator of consumption adequacy.

As a priority for the development of the methodology of the comprehensive evaluation of the FSS in the European environment of the agricultural market, it is necessary to highlight the transmission of its channels, which are based on new directions of stabilisation of production in agriculture using methods of assessing lost opportunities due to the lack of selection of products relative to its potential productivity, assessment of scenarios for the development of the European agricultural market environment, assessment of the level of economic responsibility of business entities, assessment of the directions of the anti-cost mechanism, calculation of production losses, assessment of the shadow economy in industries that were practically not carried out until recently.[14]

The transmission of FSS channels is a complex multi-level structure, with a set of elements that are somehow organised into a single complex of interrelated interests and goals of an open economic system with different levels of hierarchy.[15] The main transmission tools of the FSS from their totality are financial and food channels, which detail and expand their emergence according to the following vectors: bank, commercial and state financing with certain characteristics, as well as the specialisation of enterprises and their location in the production industries, the material, technical and technological base, the system of procurement and delivery of food (Fig. 1).[16]

In accordance with the theory of systems, a safe FSS as a channel transmission ($SFSS_s$) can be presented in the following form:

$$SFSS_s = [\{a_i\},\{c_j\}],\ a_i \in A,\ c_j \in C \quad (2)$$

where, a_i – a set of elements that determine the transmission of channels of the FSS (A – a set of elements of a safe FSS); c_j – set of relationships in which these elements (C – set of relationships between elements of a safe FSS).

It is these connections that determine the emergent properties of the transmission channels of the FSS and their functions at various stages of the integration of the market of the country-recipient into the market of the country-donor. Therefore, its behavior is a peculiar set of processes (production, transportation and sale of food products) in the European environment of the agricultural market, when the transition from one process to another is determined by a certain function of the transmission channels of the FSS:

$$SFSS_s = [\{x\}, f : (x, y) \longrightarrow XD],\ x \in X \quad (3)$$

where, $x = (x_1 \ldots x_n) \in Y$ x – set of current processes in the state of transmission of channels of the FSS; $y = (y_1, \ldots y_m) \in Y$ – a set of current processes in the transmission of channels of the FSS, related to the European environment of the agricultural market; $f : (X,Y) \longrightarrow x$ – the process transition function from one channel transmission of the FSS to the next, which changes depending on internal parameters and the influence of external factors on the development of the agricultural market; $D \in Y$ – set of available processes in the state of transmission channels of the FSS or restrictions on them.[17]

The system components of an integral object of the FSS in the European environment of the agricultural market are often related to the qualitative characteristics of the components of the FSS of the country-recipient, which function in the internal environment of the agricultural market. This can lead to an emergency – the emergence of a new synergistic connection between the components of the transmission of the financial (product) channels of the FSS of the donor country, which requires them to loosen restrictions for the recipient country on integration into the European agricultural market.[18] The formation of sustainable transmission channels of the FSS of the country-recipient in the European environment of the agricultural market can be represented in the form of a logical model, where the following subsystems are distinguished – functional and integral, the structure of which is shown in Figure 2.

14 Furman, Revkova, Revkov (n 7).

15 Olena Shebanina, Anna Burkovska, Tetiana Lunkina, Alla Burkovska, 'Global aspects of food security in the world: Economic dimensions' (2023) 38 Modern Economics 178.

16 Mudrak, Lagodienko, Osipova, Frother, Sokolyuk (n 13) 459; Volodymyr Gobela, Stepan Melnyk, Marian Kurlyak, 'Food security of Ukraine against the background of the war: assessment of the state and forecasting of trends' (2022) 2 Digital Economy and Economic Security 92; Olena Levandovska, 'Cognitive modeling of the economic development of an enterprise' (2023) 8 Problems of Modern Transformations: Economics and Management <https://reicst.com.ua/pmt/article/view/2023-8-04-10> accessed 28 October 2024; Olha Tkachenko, 'Cognitive modeling of complex systems' (2019) 2 Digital Platform: Information Technologies in the Socio-Cultural Sphere 11.

17 Tkachenko (n 16) 14.

18 Volodymyr Kapustyan, *Modeling of the economy* (Igor Sikorsky Kyiv Politechnical Institute 2022).

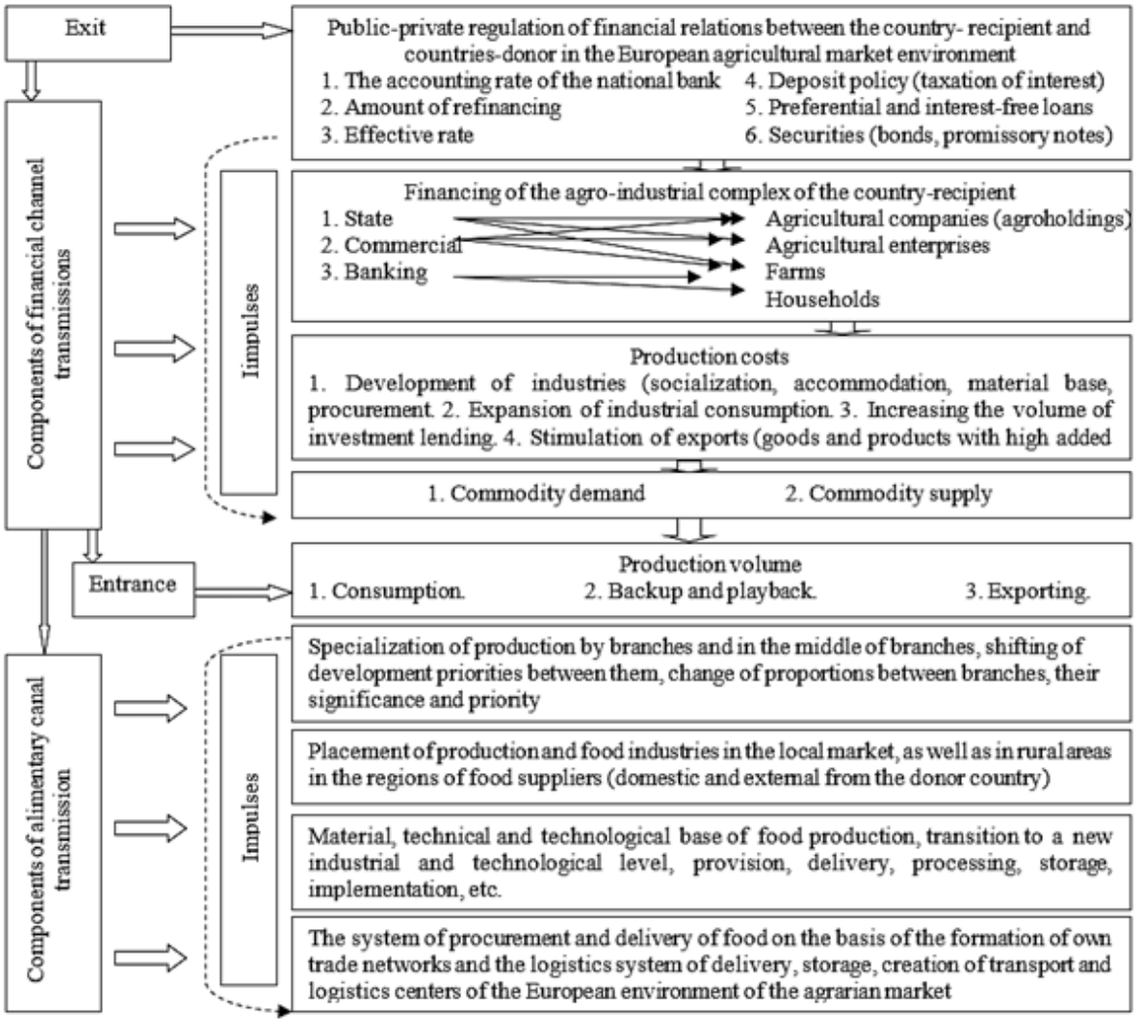

Figure 1. *Transmission of financial and food channels under fewer restrictions*

This approach allows us to take into account the dual nature of the FSS in the country-recipient: on the one hand, the transmission of its own financial channels, which are characterised by the internal doctrine of national food security, on the other hand, as the transmission of financial channels in food chains that are formed according to the laws of the European environment of the agricultural market as a whole.

The functional subsystem covers food production, the formation and distribution of a set of resources. The target subsystem implements the main goal of the transmission of the channels of the FSS – the integration of the agro-food complex of the country-recipient into public-private cooperation with the country-donor for the consumption of food products. At the same time, the system of indicators in the active stage of transmission of the channels of the FSS of the country-recipient, which is related to the European integration into the agricultural market, is a controlling subsystem and forms the integral national food security of the country. A stable and balanced model of the transmission channels of the FSS, which is developed on the basis of a functional subsystem with an orientation to reasonable food standards with effective production, financial and bioclimatic potential, is a determining qualitative vector of increasing food supply for the population.

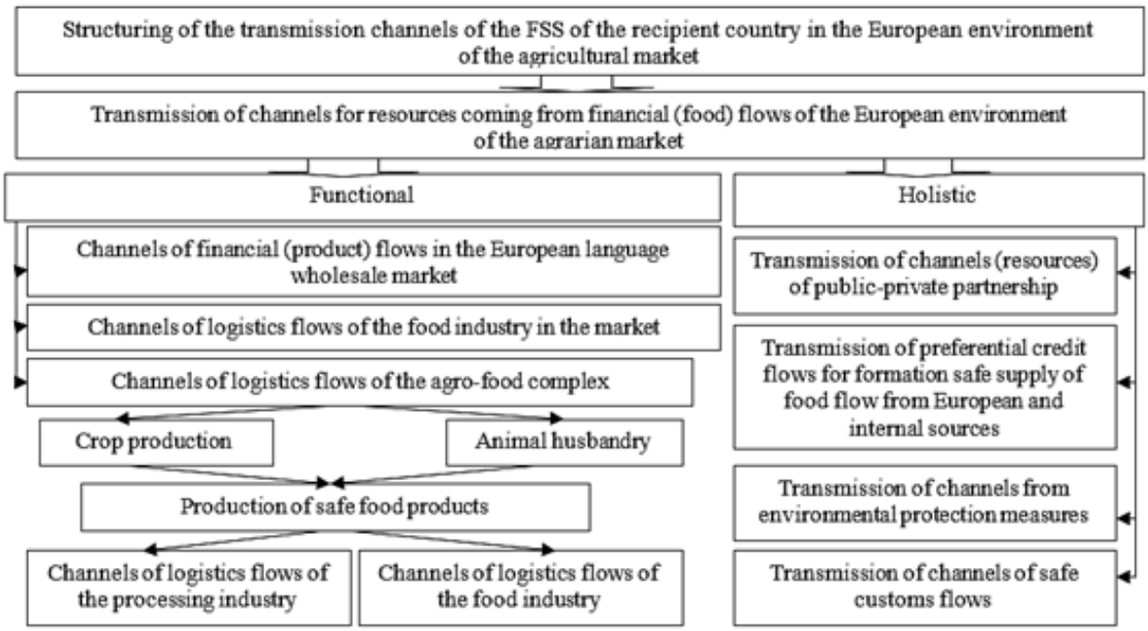

Figure 2. *Logical model of the FSS transmission channels of the country-recipient*

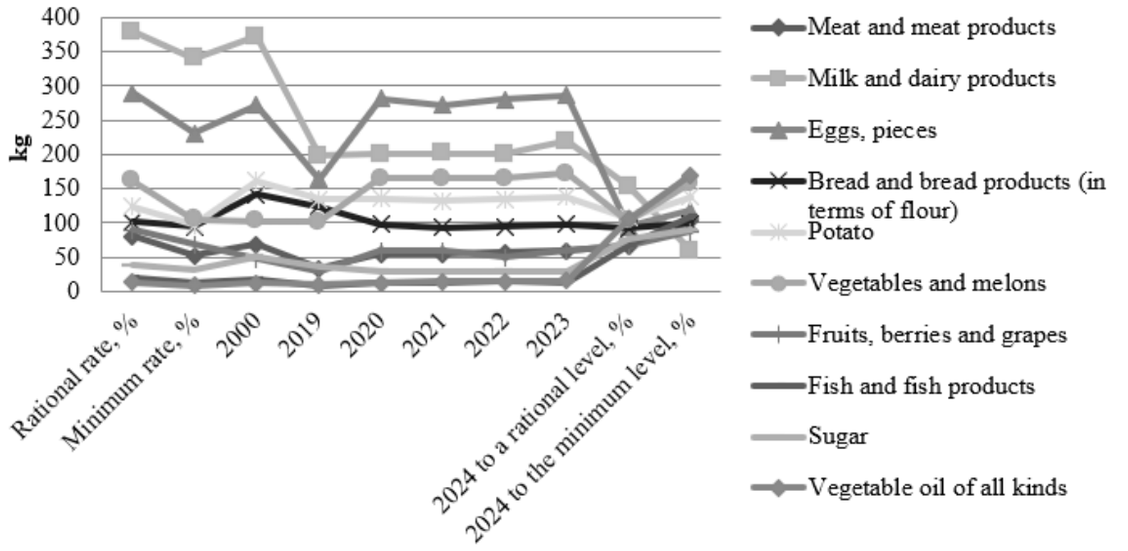

Figure 3. *Level of food consumption per person in Ukraine for 2000-2024*

III. Results

Providing the population with food is the main task of any country-recipient, which is located in the European integration vector of the development of the agricultural market. At the same time, the stability of the domestic food market enables the country-recipient to conduct an independent internal and external policy regarding the food needs, health and active life of the population, their ability to have physical and economic access to sufficiently nutritious food that meets all high quality standards.

The Food Security Index (FSI) is updated annually and in the course of the study it was found that in

2000-2023, even with a sufficient level of availability of basic food products in Ukraine, as a recipient country of European development, a significant deviation of their consumption from the rational norms recommended by health care was observed (Fig. 3).[19]

In Ukraine in 2022-2023, the shortage of meat and meat products was most acutely felt – an average of 28.1% or 22.5 kg/person; milk and milk products 18.3% or 169.8 kg/person; eggs – 2.1% or 6 pieces/person; bread and bread products (in terms of flour) – 5.2% or 5.3 kg/person; fruits, berries and grapes – 39.8% or 35.8 kg/person; fish and fish products – 33.3% or 6.7 kg/person; sugar 24.2% or 5.4 kg/person. Only the indicators of the consumption of potatoes, vegetables and melons, as well as vegetable oil of all types, exceeded the consumption norms by 12.3 kg, 7.5 kg and 1.9 kg per person, respectively, or by 4.7%, 9.9% and 14.6%, respectively. In 2024, the deficit of meat and meat products was 33.7%, eggs – 6.2%, bread and bread products (in terms of flour) 8.2%, fruits, berries and grapes – 34.3%, cottage cheese – 25%. Only the indicators of consumption of milk and milk products, potatoes, vegetables and melons, vegetable oil of all kinds exceeded the norm by 53%, 6.8%, 3.0% and 4.6%, respectively.[20] That is, the energy requirement in the diet has imbalances and does not meet the rational norms of human nutrition, according to which products of animal origin in the structure of the diet should occupy at least 55.0%.

For Ukraine, as a recipient country in the European environment of the agrarian market, the systemic problem is the insufficient level of caloric content of the daily human diet, which in 2021-2024 was 86.4-84.0% of the optimal (3100 kcal). In 2023, compared to 2015, the average daily calorie content of one person's diet in Ukraine decreased by 4.7% and amounted to 2667 kcal, in 2024 – by 4.9% and amounted to 2661 kcal.[21] In EU countries, the average daily caloric content of one person's diet is 3456 kcal. At the same time, the share of animal products in the diet in the EU is at the same level as in Ukraine – 29.3% (1012 kcal).[22] This allows us to draw a conclusion about the deterioration of the economic availability of food due to a decrease in the level of its purchasing power.

The state of the European Food Security Index (FSI), which takes into account four key criteria (economic availability of food, economic availability of food, its quality and safety, stability and adaptation), is deteriorating. In 2022, the highest level of food security was in the donor countries of the agricultural market – Finland, Ireland, Norway, France, and the Netherlands (Fig. 4).[23] However, most countries face an unprecedented increase in food prices and problems with the spread of malnutrition.

In Ukraine, there is a decrease in the level of self-sufficiency in basic consumer products during 2019-2023 (Fig. 5).[24]

Ukraine, as a recipient country in the rating of FSI, has an indicator equal to 57.9 and occupies, accordingly, the 71st position. According to the indicator "Availability of food products", Ukraine scored 75.1 points out of 100 and was ranked 83rd in the rating of FSI and 26th among 27 European countries. This is due to the presence of political and social barriers, imperfect supply chain infrastructure, and insufficient development in the field of agricultural research and food access strategies. The lowest level among the indicators that characterise the security of the food supply of the population with food products in Ukraine has the indicator "Sustainability and adaptability (43.5 points out of 100 and 94th place in the rating of FSI), which reflects significant problems in the field of access and management of water resources, as well as problems in the risk management system. The only indicator that shows a high-

19 Oleksandr Solop, *Expenditure and resources of households of Ukraine* (State Statistics Service of Ukraine 2023); Global Food Security, 'Global Food Security Index Report 2022' (*Economist*, 1 May 2023) <https://impact.economist.com/sustainability/project/food-security-index/> accessed 4 November 2024; Global Food Security, 'Global Food Security Index Report 2023' (*OpenKnowledge*, 1 May 2024) <https://openknowledge.fao.org/server/api/core/bitstreams/f1ee0c49-04e7-43df-9b83-6820f4f37ca9/content/state-food-security-and-nutrition-2023/food-security- nutrition-indicators.html> accessed 4 November 2024; Kyiv School of Economics, 'Overview of food security and policy' (*KSE*, 25 August 2022) <https://kse.ua/ua/oglyad-prodovolchoyi-bezpeki-ta-politiki/> accessed 28 October 2024; FAO, 'World Food Situation' (UN Food and Agriculture Organization, 4 September 2023) <https://www.fao.org/worldfoodsituation/en> accessed 7 October 2024.

20 Solop (n 19) 247; Kyiv School of Economics (n 19);

21 ibid.

22 OECD, 'Final consumption expenditure of households' (*OECD Data Explorer,* 13 November 2023) <https://stats.oecd.org/Index.aspx?DataSetCode=SNA_TABLE5> accessed 15 September 2024.

23 Global Food Security, 'Global Food Security Index Report 2023' (n 19); Eurostat, 'Structure of consumption expenditure by COICOP consumption purpose' (*Eurostat*, 27 November 2024) <https://ec.europa.eu/eurostat/databrowser/view/HBS_STR_T211/default/table?lang=en> accessed 1 December 2024

24 Kyiv School of Economics (n 19); FAO (n 19).

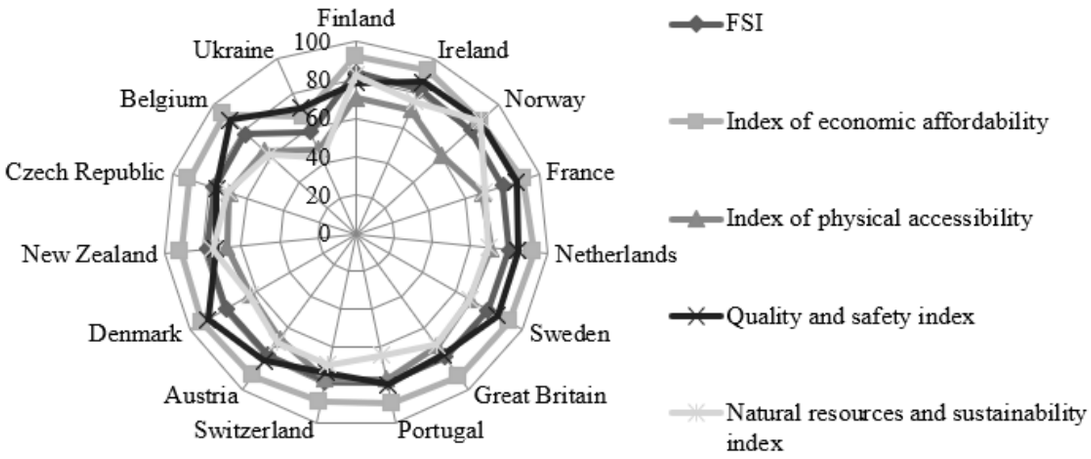

Figure 4. *Level of food consumption per person in EU donor countries in 2023*

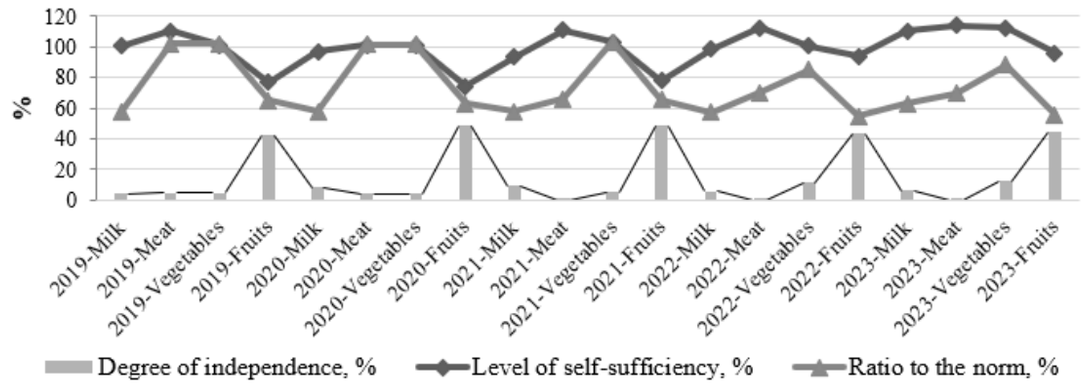

Figure 5. *Indicators of food self-sufficiency in Ukraine for 2019-2023*

er level is the factor "Food quality and safety" - Ukraine received 95.7 points out of 100 or 62 steps in the rating of FSI. Ukrainians consume enough high-quality protein; food products are safe, but the diet of the average Ukrainian is not characterised by diversity.[25]

In order to understand the state of Ukraine's economy during the war period, according to the FSI rating, a SWOT analysis of the FSS of Ukraine was conducted. The strong side (S) has more than 75 points out of 100 points, the weak (W) has less than 25 points out of 100 points, the other factors (O) are in the range of 25-75 points (Table 2).[26]

The state of the agro-food sector in Europe shows that every year its FSS becomes more and more dependent on the bioclimatic conditions of the use of production opportunities. Today in Europe, about 0.2% of the population suffers from widespread malnutrition. In 2022, the number of such a population reached 0.08 million people (Fig. 6).[27]

For comparison, it should be noted that the highest level of food security is in the countries of Central and East Africa, South Asia, and the Caribbean. At the same time, during 2010-2022, no significant

25 Global Food Security, 'Global Food Security Index Report 2022' (n 19); Global Food Security, 'Global Food Security Index Report 2023' (n 19).

26 ibid.

27 OECD (n 22).

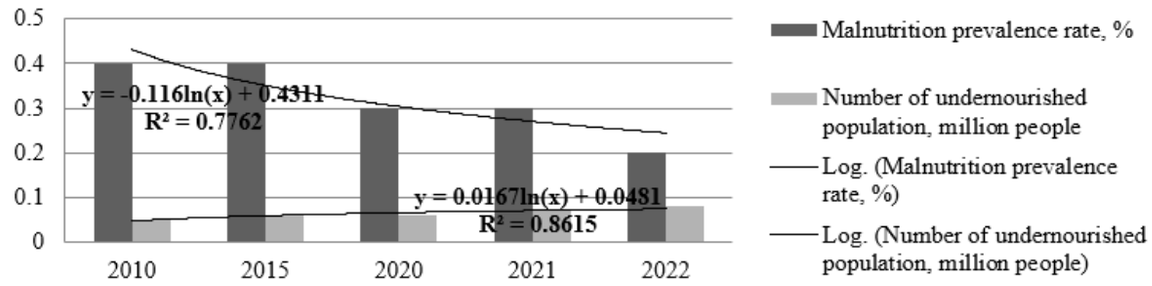

Figure 6. *Food security indicator dynamics in Europe in 2022*

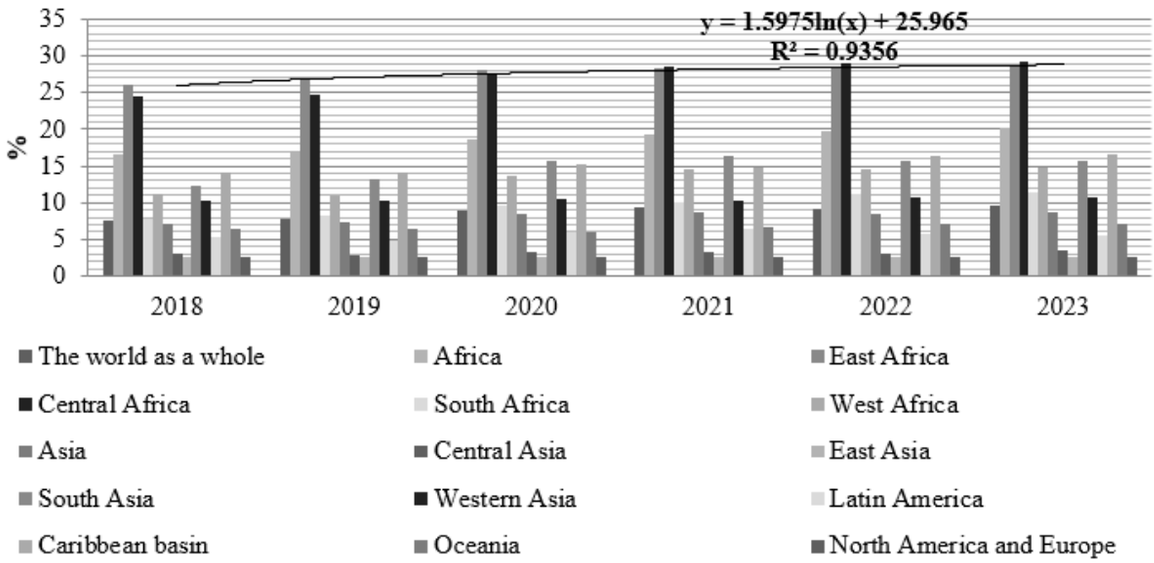

Figure 7. *Index of the distribution of malnutrition for 2018-2023*

progress was achieved in overcoming this problem. The rate of decrease in the level of hunger in these regions remains extremely slow (Fig. 7).[28]

The hostilities in Ukraine have worsened the security of the FSS, as huge amounts of crops have been destroyed, as well as agricultural and other civilian infrastructure. Significant areas on which it was possible to grow agricultural products remained unused due to mining. Due to the blocking of the export of agricultural products, the prices of fuel and mineral fertilisers on the world market increased sharply in Ukraine, which in turn complicated the activities of subjects of the agro-food sector and the state of national food security in the state, as well as exacerbated the problem of hunger in the world.[29] Nevertheless, Ukraine, despite all the challenges and difficulties of the martial law, plays a significant role in the European agricultural market – the agro-food sector contributes 10-15% of the gross added value to the state and is one of the main budget-generating sectors of the economy.[30]

28 World Bank, 'Agriculture, forestry, and fishing, value added (constant 2015 USD)' (*World Bank Group*, 13 May 2023) <https://data.worldbank.org/indicator/NV.AGR.TOTL.KD?view=chart> acccessed 8 October 2024; World Bank, 'Population, total' (*World Bank Group*, 24 August 2023) <https://data.worldbank.org/indicator/SP.POP.TOTL?view=chart> acccessed 8 October 2024.

29 Khaietska, Loianich (n 12).

30 Ukrainian Agrarian Export Association, 'Agro-food exports of Ukraine for the first six months of 2024' (*Uaexport,* 11 July 2024) <https://uaexport.org/2024/07/18/agroprodovolchij-eksport-ukrayini-za-shist-misyatsiv-2024-roku/> accessed 9 September 2024.

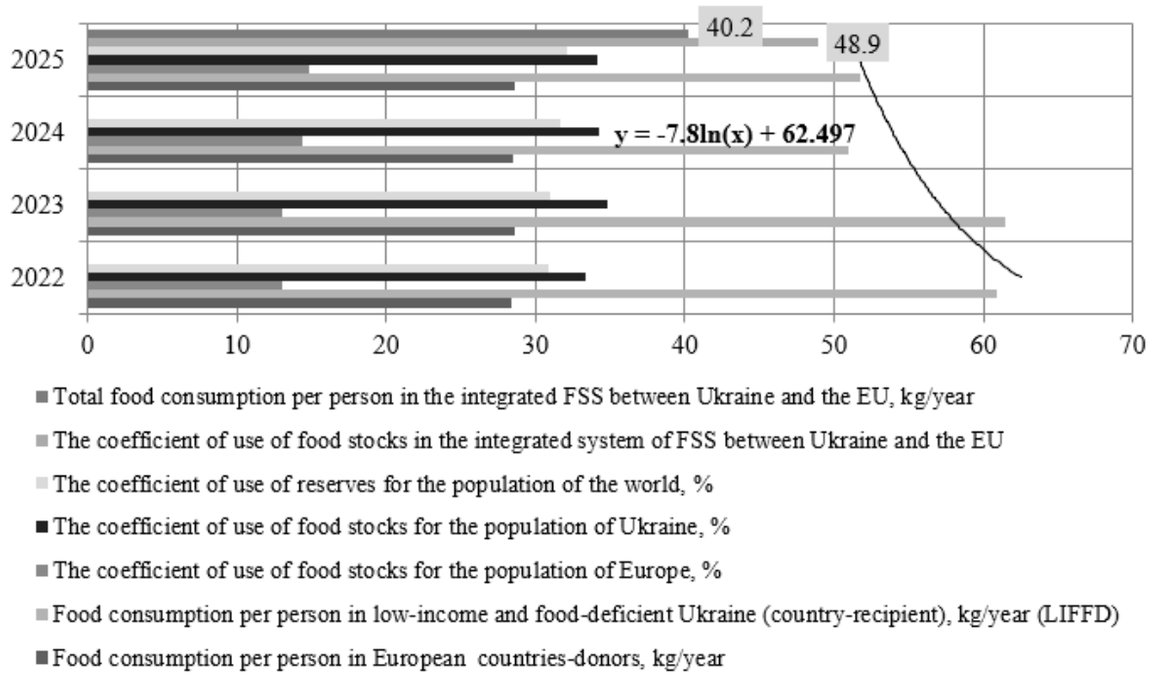

Figure 8. *Integrated indicators of the FSS between Ukraine and European countries*

IV. Discussion

Food security in Ukraine depends on the economic availability of the population, and, therefore, donor countries should consider the possibility that the war in Ukraine, and therefore the food crisis, will not end in the near future. Therefore, a solution needs to be developed that will address both globally traded goods and domestically produced goods to prevent the continuation or worsening of the global food crisis. Any decision should include preventive actions aimed at providing the most vulnerable people with the means to ensure their own food security in the medium term (Table 3).[31]

To strengthen of the FSS in Ukraine (the recipient country) among European donor countries, it is recommended to implement the following measures: implementation of reforms to increase the real income of the population (especially the socially vulnerable population), increase the level of employment in the settlement; increasing the volume of exports of food products with high added value; use of non-tariff methods of import regulation; increase in reserve food stocks; introduction of subventions for the development of infrastructure, state price support for agricultural products and resources for their production, etc.

On average, the overall utilisation rate of European food reserves is 23.6% and has a downward trend over the last 2020-2023 years.[32] For 2022-2024, the total volume of agricultural food production and processing in Europe increased by only 0.2% and equaled 1513 million tons. The volume of food stocks in Europe increased by only 0.3% (up to 366.2 million tons) (Fig. 8).[33] Therefore, the entry of Ukraine (the recipient country) into the environment of the European agricultural market will allow increasing the growth of food stocks within the average European level and stabilising the consumption of quality food products per person of the population.

31 Overkovska (n 7) 226; Urba, Kopytko (n 7) 59; Nikoliuk, Atamas, Shumilov (n 8) 62; Anatolii Getman, Tetiana Kurman, *Agrarian and land law of Ukraine: modern paradigm and prospects for development* (Yurayt 2022); Tetiana Kharitonova, Khrystyna Hryhorieva 'Food security in the conditions of modern military conflicts: Legal experience of foreign countries' (2023) 2 Legal Scientific Electronic Journal 287.

32 FAO (n 19).

33 Solop (n 19) 203; Global Food Security, 'Global Food Security Index Report 2023' (n 19); FAO (n 19); World Bank, 'Population, total' (n 28).

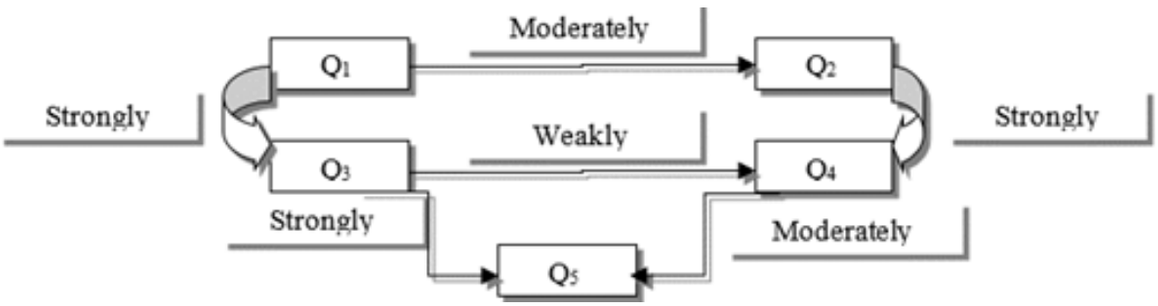

Figure 9. *Influence levers on FSS channels in the European agricultural market*

The cognitive algorithm for modeling the transmission channels of the FSS to ensure the economic availability of food for the population in the European environment of the agrarian market allows to form a hypothesis about its safety of functioning as an object of a complex system, which consists of the following stages: identification of factors characterising the real situation in the environment; identifying relationships between factors, determining the direction of interaction between factors and their characteristic features of influence (positive, negative) in an oriented graph; determining the level of influence of factors on each other (weak, strong) and building a cognitive model.[34]

PEST analysis in fuzzy cognitive maps allows you to determine the weight of the influence of components – this is a number from the interval [-1; 1] or a value from the logistic scale, which characterises the strength of the change in the corresponding relationship or the degree of confidence in its presence (weak, moderate or strong). To analyze the change in the equivalent impact of components Q1 and Q5, it is necessary to consider all existing possibilities from components Q1 to Q5. That is, the application of PEST analysis allows us to identify four main groups of behavior of the studied object of a complex system,[35] which are interconnected and characterise different hierarchical levels of transmission channels of the FSS of the recipient country and its security in the European agrarian environment market. Equivalences of the impact of the set of components of the transmission channels of the food supply system (FSS) of the recipient country, which adopt certain safety features in linguistic chains, are shown in Figure 9.

With the help of the Fuzzy-Logic Cognitive Mapping (FCM) cognitive model, the transmission of the channels of the FSS of the recipient country is modified according to paired structural connections, which are indicative in cognitive maps, in the form of a set of factors – $F=\{f_i\}$. A set of indicators are used as measuring scales of the researched factors by components of the food security system (FSS) of the recipient country, which allow them to be integrated into a single numerical configuration with linguistic values (Table 4).

These values determine the adjacency matrix $W=\{w_{ij}\}$, $w_{ij} \in \{-1,0,1\}$. At the same time, the interpretation of negative values of the indicator (situation factor $f_i \in F$ is supplemented by a factor that has the opposite meaning, i.e. f_1. This convenient approach allows modeling multipolar increments of factor values to describe the transmission of logistics processes in the channels of the FSS of recipient countries integrating into the European environment of the agricultural market. Scenario analysis "If...then..." to determine the system's response to possible changes. In matrix form, the solution system is written as follows: $J(t+1) = Wj(t)$ (4)

where, $J(t) = (j_i(t))$ – the initial vector of growth of factor values at the moment of time t; $J(t+1) = (j_i(t+1))$ – the vector of growth of factor values at the moment of time $(t+1, j_i(t) \in -1,1 ; W = |w_{ij}|$ – adjacency matrix; $w_i \in -1,1$ – characterises the strength of the connection.

34 Tkachenko (n 16) 14; Kapustyan (n 18) 117.

35 Anastasia Kaplina, 'Methodical apparatus of cognitive modeling of the socio-economic system' (2023) 6 Efficient Economy <http://doi.org/10.32702/2307-2105.2023.6.18> accessed 23 October 2024

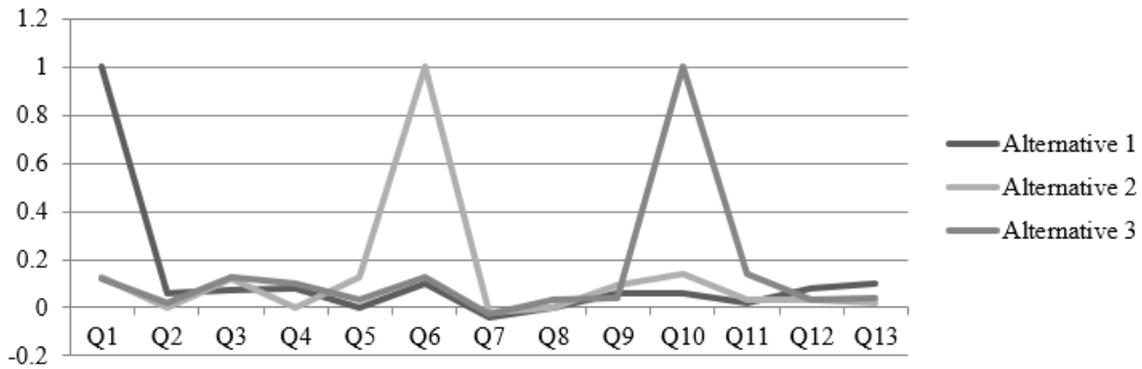

Figure 10. *Analysis of security the FSS of the country-recipient. Note. Increase max (Alternative 1 – Component Q_1; Alternative 2 – Component Q_6; Alternative 3 – Component Q_{10}).*

The growth of factor values at discrete moments of time is presented as $J(t + 1),..., J(t + n)$ which is calculated using the composition rule:

$j_i(t) = max(j_i + (t), j_i - (t))$ (5)

where, $j_i + (t) = max(j_l (t-1)w_{il})$ – maximum positive; $j_i - (t)$ – the maximum by the modulus is negative ; $j_i - (t) = max(j_l (t-1)w_{il})$ increase in the value of the effect factor.

Scenario analysis of the growth of three components of the FSS model (components Q1, Q6 and Q10), allows you to determine their potential maximum growth to factor $fi \in F + 1$ (Fig. 10).[36]

Source: calculated and constructed by the authors

The results of the three-component indicative model show that in alternative 1, with the maximum value of the Q1 component (+1), two components show the greatest increase: Q6 (+0.10) and Q13 (+0.10). In alternative option 2, at the maximum value of Q6 (+1), four components demonstrate the greatest increase: Q10 (+0.14), Q1 (+0.13), Q5 (+0.13), Q3 (+0.12). In alternative option 3, at the maximum value of Q10 (+1), four components show the greatest increase: Q11 (+0.14), Q3 (+0.13), Q6 (+0.13), Q1 (+0.13).

In the three alternative options, there is a decrease in component Q7 (-0.04; -0.02; -0.03, respectively), which is an underdeveloped potential direction of the future prospects of the transmission channels of the FS of the country-recipient to expand opportunities in the countries-donors of the European agricultural market environment.

Thus, the use of the cognitive model of the transmission channels of FSS in Ukraine, under the condition of integration into the European environment of the agricultural market, as a complex multi-level configuration of interconnected components, allows the use of the tool of dialectical cognition of the impulse of a set of factors and their levels according to a set of safe alternative options (FCM-model), in order to optimise programs of public-private cooperation in the field of food supply of the population with food products, on the basis of coordination of legal acts with European countries-donors, regulation of national interests in accordance with the concept of foreign economic strategy and security narrative of the UN and other international organisations.

According to European social standards, households of all decile groups are food insecure in Ukraine for the period of 2024-2025. The same conclusions are confirmed by an international comparison (Fig. 11).[37]

Despite the fact that Ukraine is one of the world leaders in agro-food production and export of agricultural products, the acute social problem in the country is the low level of economic availability of food. The constructed linear regression model made it possible to test the hypothesis that the growing volume of food production in Ukraine is not a sufficient condition for ensuring the national FSS in terms of the economic availability of food.

36 ibid.

37 Solop (n 19) 205; OECD (n 22); Eurostat (n 23); World Bank, 'Agriculture, forestry, and fishing, value added (constant 2015 USD)' (n 28).

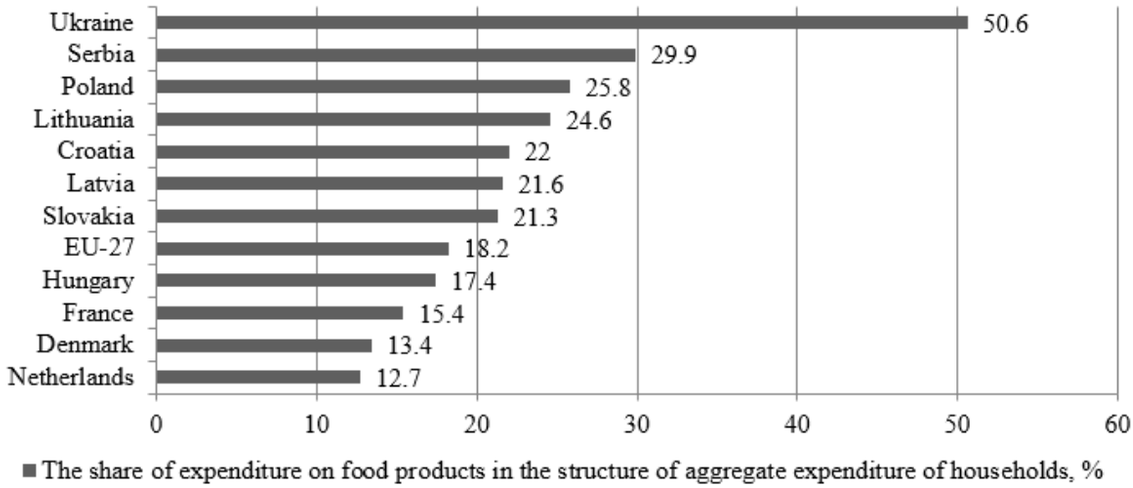

Figure 11. *International comparison of household food expenditure*

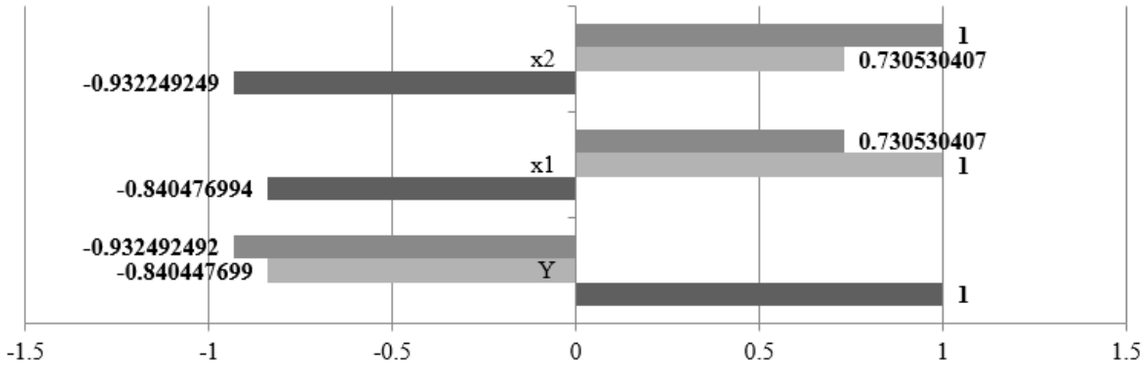

Figure 12. *Correlation matrix*

Analysis results: correlation coefficient $R = 0.964$ – the hypothesis of a close relationship is confirmed; coefficient of determination $R^2 = 0.911$ – the variability of the function is determined by 91.1% variability of the selected factors; Fisher's test $F\,f = 95.717$, $F_c = 4.533$, $F\,f \geq F_c$. The hypothesis of the existence of a relationship between indicators is confirmed; Student's criterion (t): $t_f = 46.5$, $t_c = 3.104$, $t_f \geq t_c$. The hypothesis about the statistical significance of the regression coefficient is confirmed; check for collinearity (x^2 Pearson): $x^2_f = 15.911$, $x^2_c = 4.952$, $x^2_f \geq xf$; regression equation: $Y = 83.191 - 0.048x_1 - 0.02x_2 + \varepsilon$.

The hypothesis of collinearity is confirmed. However, there is a condition of admissible collinearity, which does not distort the results of the study: the paired correlation coefficients between the factor and result characteristics are greater than the correlation coefficient between the accompanying factors: ${}^{rY}x_1 \geq {}^{r}x_1x_2$; ${}^{rY}x_2 \geq {}^{rY}x_2$ (Fig. 12).

When checking the reliability of the results of linear multiple regression, similar calculations were made for France, Denmark, Slovakia, Latvia, Croatia, Lithuania, and Poland. It turned out that the condition of admissible collinearity ${}^{rY}x_1 \geq {}^{r}x_1x_2$; ${}^{rY}x_2 \geq {}^{rY}x_2$ is fulfilled only for France and Slovakia; there is no collinearity in the calculations for Denmark. To determine the weighted share of the influence of each of the factors on the variability of the result indicator, a breakdown of the overall variation in the share

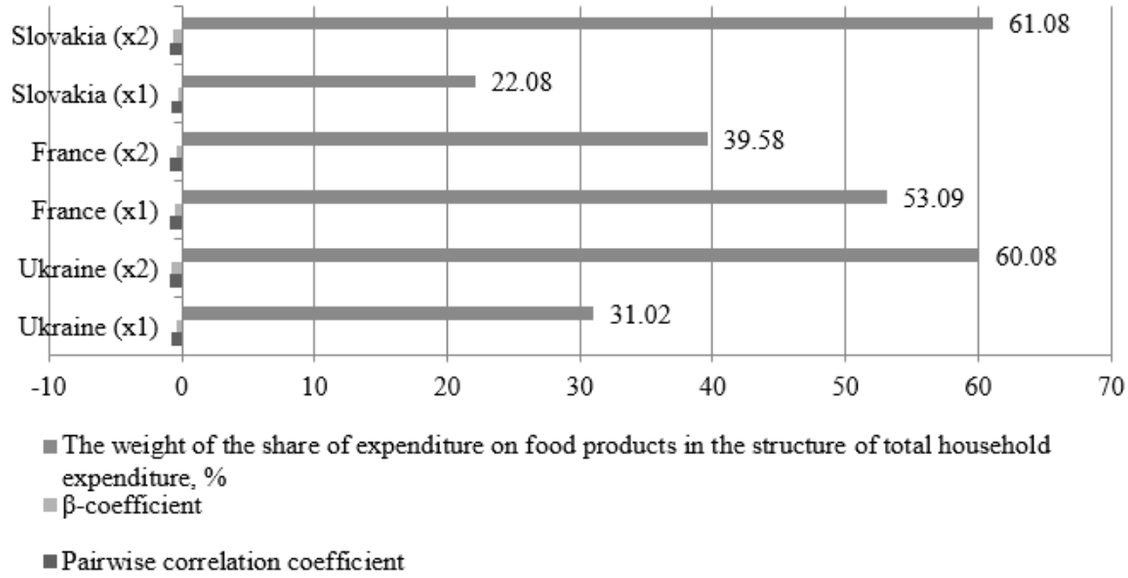

Figure 13. *Food expenditure share in Ukraine and Europe for 2024-2025*

of food expenditures in the structure of aggregate expenditures of households in Ukraine and European countries was carried out (Fig. 13).

Consequently, the reduction of the share of expenditure on food products in the structure of the aggregate expenditure of households of Ukraine, i.e. the increase in the economic availability of food, which will depend on 60% of the level of income per person and only 31% on the amount of agro-food production per person. In Slovakia, the size of the influence of the volume of income per person will be almost equal to the level of economic availability of food in Ukraine. In France, it will amount to 39.6%, yielding to the influence of the volume of agricultural production. The experience of France indicates the possibility of alternative options for the development of local FSS for the harmonious combination of measures to stimulate the food situation.

It is assumed that with interrelated factors of influence, the coefficient of food elasticity in Ukraine allows to increase the GDP per person by 1%. At the same time, the share of expenditure on food products in the structure of total household expenditure will decrease by 0.424% every year (from 2024 to 2025). The average annual growth rate will be +3.8%. That is, due to the increase in income per person, the share of expenditure on food products in the structure of total expenditure of Ukrainian households will decrease by an average of 1.61% every year.

The average value of the share of expenditure on food products in the structure of aggregate expenditure of European households in 2024-2025 will be 18.2%. Provided that the dynamics of economic growth and the peculiarities of the distribution of GDP in Ukraine are preserved, this indicator could be reached only after 20 years – in 2044. It is worth noting that 50.2% – the average size of the share of expenditure on food products in the structure of aggregate expenditure of Ukrainian households in 2024; 12.8% – expenses for housing, water, electricity, gas and other types of fuel; spending on clothes and shoes 7.7% of all spending; expenses for transport and communication – 5.6%.[38] It is clear that this is too long a period to achieve the desired (European) level of one of the key indicators of a safe FSS, and the standard of living of Ukrainian households. However, in the conditions of the country's martial law, it seems unattainable the economic situation in the country has deteriorated sharply. Therefore, the integration of agrarian food into the EU is considered extremely necessary.

38 World Bank, 'Population, total' (n 28).

V. Conclusion

Therefore, Ukraine needs an immediate settlement of the issue of ensuring a safe system of food supply to the population. The current crisis also calls for a review and reorganisation of the country's food system, making it more equitable, sustainable and adaptive in times of dire need. To avoid new crises like this in the future, it is necessary to diversify food production across different industries, supply chains and markets, and to address the problems of indebtedness, economic injustice and market distortions that contribute to the emergence of crisis factors.

There is a need to continue to support Ukrainian farmers and the entire private sector by providing key resources for next year's growing and harvesting. In addition, the further implementation of innovative technologies, business models and data exchange mechanisms will make it possible to make the production of food products in Ukraine and their export more efficient. This will require cooperation between the agricultural sectors of Ukraine and the countries of the European partnership to exchange data on production, accumulation, supply chain and other relevant data through clearinghouses, in order to ensure the availability of information.

It is also worth considering the experience of resolving disruptions related to the country's martial law, which forces agricultural market participants in many EU countries to accelerate the implementation of digital tools, which will lead to greater transparency of information on agricultural data. This will make it possible to better aggregate the products of small farms. In addition to supporting Ukrainian farmers, the public-private sector should consider investing in new financial mechanisms to support small and medium-sized enterprises, including farmers, where sustainable large-scale production will require innovation and financial resources.

To improve the level of the food supply system, it is necessary to improve the existing mechanisms of the functioning of the agro-food sector and its maximum convergence with the economic, social and environmental goals of the EU development based on the principles of self-sufficiency, multifunctionality, social justice, independence, stability, balance and rationality. The implementation of these principles requires making changes in the functioning of the agricultural market, in particular in terms of improving the physical availability of food, spreading business insurance in the agricultural sector, and optimising the system of distribution of products on the market. Increasing the economic availability of food products, reducing the difference in income between different strata of the population, as well as guaranteeing the quality and safety of agricultural products through the improvement of technical regulation mechanisms in the agrarian sector of the economy are important directions of Ukraine's cooperation with the EU.

Appendix

Table 1. *Conceptual principles of security for FSS in EU agriculture*

Strategic vector	A paradigmatic feature
I – self-sufficiency	Own agriculture and own food complex, including production, processing and a system of large food bases and storages located in adjacent natural agar zones
II – obligation	Ensuring the necessary level of safety of the FSS, as the most important condition for the sustainable development of agricultural and food industries, the stable development of cities and rural areas
III – organisational and economic	Formation of the mechanism of accelerated development of the system of increasing own production and food supply, development of the system of chain food supplies to stabilise the level of consumption of products and their safety
IV – cluster	Maximum development of the system of large (export/import) chain supplies between the country-recipient and the country-donor for the formation of reserve food bases, close and accessible in terms of transport, ensuring high quality at affordable prices for food products
V – import substitution	Gradual elimination of dependence on imported food due to restrictions and the mechanism of food quality requirements, economic levers and the maximum intensive increase in the production of own import substitute products of better quality
VI – efficiency	Increasing the socio-economic effectiveness of agricultural industries, ensuring the stability of activity indicators
VII – logistic	Formation of a system of transport and logistics centers (domestic, export) to ensure stability and guarantee of obtaining food products, reducing food delivery costs
VIII – reservation	Formation of a system of strategic reserves, insurance stocks of food, material and technical resources with appropriate legislative and regulatory support
IX – marketing	Creation of a procurement and sales system, expansion of the network of large and medium-sized retail outlets in cities and rural communities to ensure own agricultural and processing products
X – informative	The use of modern information systems and technologies to monitor the state of security of the FSS, conduct analysis and modeling of the long-term development of the FSS

Table 2. *SWOT analysis of the FSS of Ukraine in 2023*

Strengths (S) (> 75 points)		Weaknesses (W) (< 25 points)	
Indicators	Evaluation, points	Indicators	Evaluation, points
Proportion of the population below the poverty line	99.9	Corruption	0.0
Food quality and safety	95.7	Food standards	0.0
Changes in the average cost of food products	94.5	Budget expenditures on research and development in agriculture	1.1

Crop losses	90.4	GDP per capita, EUR	6.8
Food availability in cities	75.1	The risk of shelf stability	+16.7
Tariffs for the import of food products	85.5		
The influence of general indicators on the level of the FSS of the population with food products			
GDP per capita, EUR		Low (–)	411.2
Population, million people		Low (+; –)	31.1
Land area, km²		Low (+; –)	32.1
Prevalence of malnutrition, %		Low (+)	3.5
Intensity of food loss, kcal/person-hour		Low (+)	18
Human Development Index		Low (+)	0.75

Table 3. *Preventive measures for forming a safe FSS of Ukraine*

Levers	Donor countries and exporters	A recipient country experiencing a food crisis	Multilateral organisations and development institutes	Public organisations and the social sector	Private sector
Consumption	Coordination of net exporters to release product stocks and identify opportunities to increase resource compensation in the event of food shortages	Encouraging farmers to grow traditional and alternative nutritious foods	Support for agricultural development and food security programs to support food production	Working closely with government and the private sector to provide emergency food assistance	Supporting the production of nutritious food products (investment in research and development, sourcing and logistics). Application of innovative technologies to ensure the sustainability of the food system
Agrarian potential	Provide financial and technical support to smallholders, including resources and tools	Implement measures to prevent hoarding of resources and price increases	Support of agricultural development programs and formation of a safe food supply system	Work with net importers and exporters to improve access and resource efficiency	Facilitate access to key resources for production in Ukraine (on the territory of rural communities)
Financial support	Investing in expanding monitoring of international aid. Restoration of the infrastructure of Ukrainian agriculture	Providing limited subsidies targeting small farmers with a clear action plan to gradually pull out of the recession	Debt restructuring or the formation of debt swaps related to the sustainability of small commodity producers	Application of effective money transfer programs	Investing in new financial instruments to support small businesses for long-term growth of income from the sale of food products on the agricultural market
Policy	Waiver of export ban	Development of an action plan for strengthening lo-	Encouraging the European Trade Organization	Increasing food and financial aid, as well as	Collaboration between industries and governments to share manu-

		gistics flows and chains of quality products, as well as creating added value in the country	and other international organisations to abandon restrictions on export operations	easing restrictions on food and fertiliser exports	facturing experience and build supply chains

Table 4. *Component system for the safe integration of the transmission channels*

Component	Description
Component Q1 – the activity of public-private cooperation between the country-recipient and European countries-donors in regulating the development of the agro-food complex	Stable development and availability of reserves for increasing food production, renewing and increasing stocks in the light of public-private cooperation with European countries
Component Q2 – incomplete development of the doctrine of safe food supply in the country and its compliance with the requirements of the European agricultural market	Consistency of laws regarding the security of the country's food supply, regulation of national interests in accordance with the concept of foreign economic strategy and the security narrative of the UN, the EU and other international organisations
Component Q3 – uncertainty in the development priorities of agriculture and food industry	Provision of basic food products of national production
Component Q4 – uncertainty in the land market, irrationality of agricultural land use	Regulation of the land market, determination of agrarian and land policy
Component Q5 – developed infrastructure of agricultural production and food supply entities	The ability to maintain the stable capacity of the subjects and ensure the proper living conditions of the population
Component Q6 – favorable investment climate	Attracting financial resources from public-private partnership on the European agricultural market
Component Q7 – is a strategy for stimulating the logistics flows of agricultural production and processing	Growth of export logistics flows from the production of agricultural and processing products
Component Q8 – proper product quality and safety	Provision of economically clean and useful products
Component Q9 – low purchasing power of the population	Food prices are affordable for the working population, large families, and pensioners
Component Q10 – is a positive agrarian image	Increasing production efficiency, restoration and development of rural areas
Component Q11 – development of innovative approaches to nutrition based on the development of agricultural production and processing technologies	Provision of all areas of production with the latest models of equipment, technologies; probable forecasts of the development of innovations in food
Component Q12 – accumulation of strategic food stocks	The possibility of avoiding hunger if the food distribution norms are introduced for five years
Component Q13 – lack of a long-term forecast of food security in the country	Achieving the goals of food supply in conditions of limited resources in the material, technical and production potential