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Том 2, № 1, 2024

SMART ECONOMY, ENTREPRENEURSHIP AND SECURITY

Vol. 2, № 1, 2024

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ЗМІСТ

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ANALYSING MIGRATION RISKS IN THE MANAGEMENT OF AGRO-INDUSTRIAL ENTERPRISES IN EUROPE

Abstract. *It is impossible to imagine the effective functioning of agro-industrial companies in any country without labour resources. It is necessary to take into account that at this time there is an uneven demographic distribution in the world, and migration in the context of globalisation has acquired significant proportions. Without migrant labour, some agricultural sectors would collapse. At the same time, migrants can increase risks and reduce the efficiency of agribusiness development. It is important to monitor migration risks on time and make the necessary management decisions for the sustainable development of agro-industrial enterprises.*

The source base was statistical data on the main indicators of migration processes in Europe, in particular in geographical terms: Eastern, Western, Northern and Southern Europe, for the last 2010–2021. The methods of induction, deduction, mathematical modelling and statistical analysis of spatial (panel, longitudinal) data were used in the analysis of migration risks in the management of agro-industrial enterprises in Europe.

The results of the analysis of migration risks in the management of agro-industrial enterprises in Europe have shown that according to the coefficient of the individual effect of migration management, the leader is the group of Eastern European countries, while the outsiders are the countries of Western Europe. If we characterise and compare the obtained forecast values of individual effects and individual effects of previous years, we can conclude that the leader is a group of Western European countries. This indicates a high possibility of migration movement and migration risks in Western European countries, which are more secure and stable. Modelling migration risks in the management of agro-industrial enterprises in Europe has shown that there is a need for a systematic analysis of these processes. In particular, the instability of the institutional and market environment in European countries causes constant changes in migration trends and, accordingly, changes in the impact of migration risks on agribusinesses. This analysis is of practical importance in management activities to make timely decisions and prevent negative consequences of migration risks.

Keywords: *migration risks, management, agro-industrial enterprises, labour force, employment, migrants, agricultural products.*

1. Introduction

Human resource is the most important for the effective development of any country in the world. Migration has an unconditional impact on the development of agro-industrial enterprises. The impact of this process can be both positive and negative. It depends on different factors and characteristics. Migration can provide the agribusiness sector with a labour force. If a country or a region does not have enough labour for agriculture, migrants can compensate for the needs of enterprises for workers. Migrants can work on farms, fields, orchards, helping to increase agricultural production. At the same time, if migration processes become uncontrolled by the state, there may be an excessive saturation of the labour market with cheap labour, which will increase migration risks. Alternatively, vice versa, the existing skilled labour force may leave the country and move to another country where the pay or working conditions are better. Migrants can contribute to the economic development of rural communities by earning money for goods and services and paying taxes. Displaced people can also create new agro-projects by innovating and developing new agricultural industries that can be profitable. The impact of migration on agriculture is complex and depends on many factors, such as the scale of migration, cultural differences, level of technological development and migration risk management policies. Consequently, it is important to consider migration in the context of a specific geographical and socio-cultural situation and to consider its positive and negative aspects for agriculture or rural areas. Effective migration management can help to maximise positive impacts and minimise negative migration risks.

Many scholars have studied population migration and its impact on different socio-economic phenomena.

Qian *et al.,* [1], examined the impact of migration on the restructuring of agricultural production in Jiangxi Province. The authors proved that the Chinese government's administrative restrictions on the free movement of human resources hinder agricultural restructuring and sometimes even force farmers to abandon their farmland.

An important study was conducted by Falco *et al.,* [2], Scientists paid attention to the problems of climate change and migration in the modern world. Using a sample of 108 countries, the scientists analysed the relationship between weather, agricultural productivity and international migration. The authors' conclusions show causal links between changes in the agribusiness sector, climate and population movement.

Liu *et al.,* [3], noted that since the late 1990s, the mass migration of human resources from rural areas has affected the quality of China's land cultivation. Scholars proposed directions for improving migration and population policies.

Marchiori *et al.,* [4], analysed the impact of weather anomalies on migration in Africa. In addition, scholars have thoroughly identified the relationship between climate change and international population migration.

Mwesigye and Matsumoto, [5], conducted interesting research on the impact of demography, migration and land conflicts on the productivity of Uganda's agribusiness sector. Specifically, the paper found that demographic pressures and internal migration reduce social cohesion. This negatively affects informal land relations and generates ethnic conflicts, especially among migrants.

Li *et al.,* [6], analysed the impact of labour migration on the use of chemical fertilisers by farmers in China. The authors' research contributes to the transition to sustainable agriculture, efficient management and resource conservation.

Langill *et al.,* [7], identified the effects of intensifying migration flows on structural changes in households. The researchers concluded that population migration has strong gender specificities structurally shaping future households in rural areas.

Hermans and McLeman, [8], analysed how climate change, drought and land degradation affect migration. The researchers focused on the methods used to estimate migration, land degradation, etc.

Adhikari *et al.,* [9], conducted interesting studies on the impact of human resources on food systems in Nepal. Researchers investigated the impact of the lockdown on agriculture and food systems in Nepal and determined the effectiveness of measures to address the crisis caused by COVID-19.

Foundational studies on the impact of human resource and labour migration on land quality and agriculture have been conducted by Gao *et al.,* [10], Ge *et al.,* [11], Xu *et al.,* [12].

Of particular interest are the research studies by Halder *et al.,* [13], which analysed the impact of climate change, land degradation and migration in India. Nienkerke *et al.,* [14], have carried out an interesting study. The authors identified the impact of seasonal migration on agricultural development and suggested ways to improve food security.

These scientists have expanded the understanding of the processes of modelling the impact of population migration on agriculture, at the same time there is a need to deepen the tools of current assessment of such impact and forecasting with updated mathematical apparatus. Given the above, the aim of the article is to provide an algorithm for assessing migration risks in the management of agro-industrial enterprises in Europe.

2. Materials and Methods

The high volatility and uncertainty of the modern world require complex and flexible methods of analysing or forecasting any economic phenomena. Migration processes are difficult to predict, so for their analysis, there is a need to use different tools, approaches and modelling in the context of variable conditions. In this case, the development of spatial

(panel, longitudinal) data models that take into account regional and spatial aspects is indeed advisable in the study of migration processes and for making informed management decisions. These models will allow for a more complete and accurate differentiation of geographical and socio-cultural features of migration, which is an important step for regional development planning. For practical implementation of spatial (panel, longitudinal) data models we will carry out the modelling of migration risks in the management of agro-industrial enterprises in Europe. Using the data of statistical compilations of Ukraine 2010–2021 we have formed the initial data of the main economic and social indicators of migration processes in Europe, in particular in geographical terms: Eastern Europe, Western Europe, Northern Europe and Southern Europe, for the last 2010–2021: agricultural employment (% of employed); international migrant stock (0.00/% of total population), agricultural production index (Fig. 1).

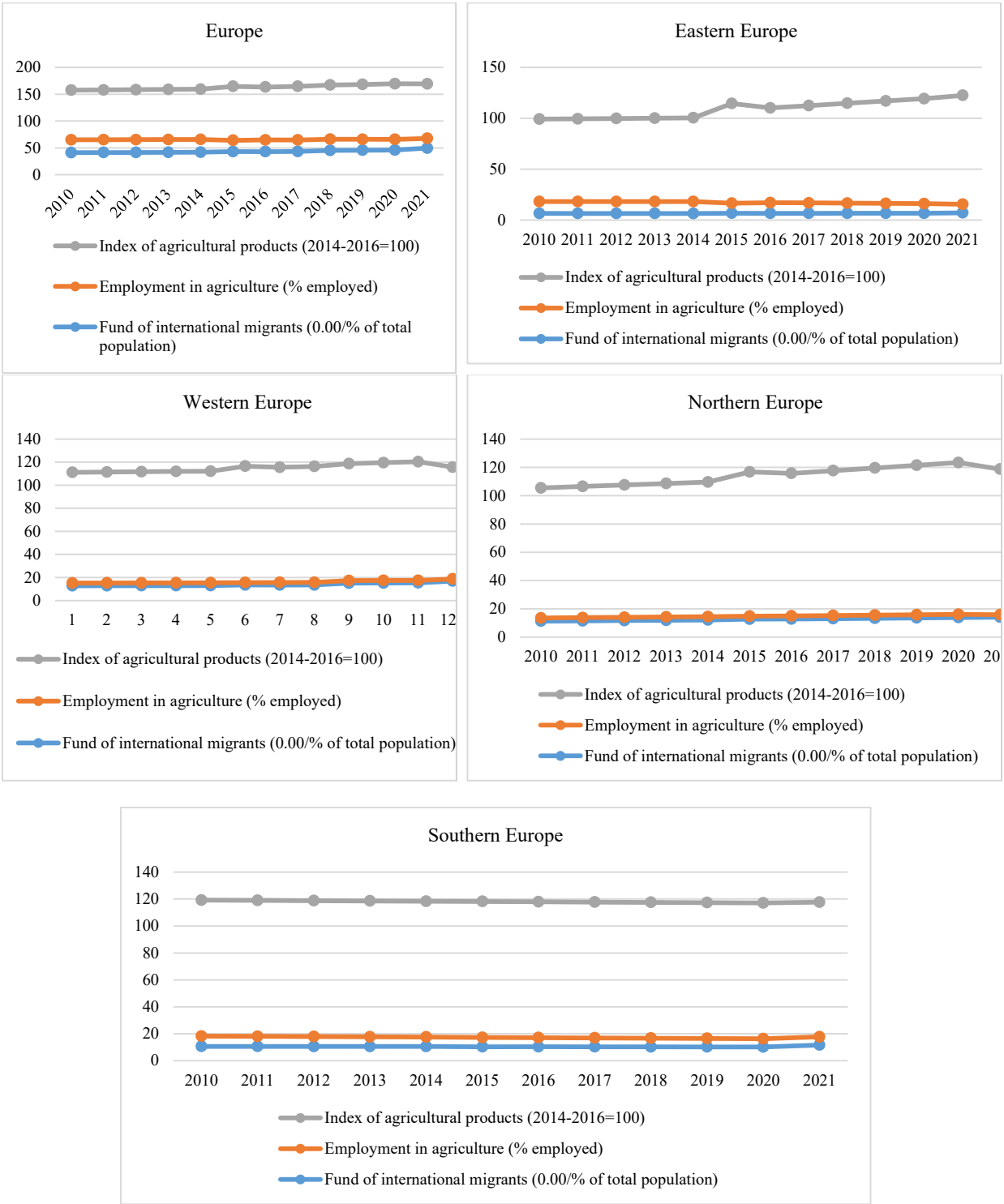

Figure 1. Input information for modelling migration risks in the management of agribusinesses in Europe Source

Source: https://www.ukrstat.gov.ua/, https://ec.europa.eu/eurostat

At the following stages, according to the rating algorithm, methods of induction, deduction, analysis, synthesis, mathematical modelling and statistical analysis of spatial (panel, longitudinal) data, we will analyse migration risks in the management of agro-industrial enterprises in Europe.

3. Results and Discussion

At the next stage of analysing migration risks in the management of agro-industrial enterprises in Europe, the ranking and averaging of the ranked series of the agricultural production index should be carried out. Ranking is carried out by the method of data ranking using the statistical function "rank". It should be noted that the ranking was based on the lowest index of agricultural products (Table 1).

The grouping of European states according to the ranking of international migrant stock, agricultural employment and agricultural production index is presented in Table 2, where European states are divided into 4 groups. In addition, attention is paid to the ranking of agricultural employment, as it can be an effective indicator of managing migration risks.

Next, we consider the construction of a spatial (panel, longitudinal) data model with fixed effects for studying migration risks in the management of agro-industrial enterprises in Europe. For this purpose, we will find the average of each model variable for each group using the built-in mathematical function "averages" (Microsoft Excel), (Table 3).

In the next stage, we calculate individual effects, consistent estimates, deviations of actual values of the indicator and factors from the average value by groups, their product and square. As a result of the calculations, we obtained coefficients to determine the individual effects of migration risks in the management of agro-industrial enterprises in Europe:

b	0,070
	−0,092

Next, we find the individual effects for each group:

1st group of Eastern European countries with the highest level of employment in agriculture $a_1 = 18.56$;

2nd Group of Southern European States $a_2 = 15.36$;

3rd Group of Western European States as $a_3 = 10.40$;

4th group of Northern European countries $a_4 = 10.46$.

Thus, according to the coefficient of the individual effect of migration management in agro-industrial enterprises in Europe, the leader is the first group of Eastern European states with the highest indicator 18.56. The outsiders are the third group of Western European countries with an index of 10.40. If we analyse the countries included in these groups, the calculation of the individual effect coefficient is clear and justified. However, it is necessary to take into account other factors of external and internal influence on migration processes in agro-industrial enterprises in Europe and take into account that this study is based solely on statistical indicators and coefficients.

Finalising this study and modelling migration risks in agribusiness management in Europe using spatial (panel, longitudinal) data models, we graphically present the individual effect coefficients in the study of migration risks in agribusiness management in Europe, 2010–2021 (figure 2).

In the next step, it is important to forecast the individual effects of migration risks in European agribusiness management using spatial (panel, longitudinal) data models for the forecast years 2024–2026.

To forecast agricultural employment, international migrant stock and agricultural production index, we use the built-in statistical function "forecast" of Microsoft Excel spreadsheets and determine the forecast value of these values for the period 2024–2026 (Table 4).

It should be noted the fluctuations of the studied factors affecting migration risks in agro-industrial enterprises. Further, as before, we consider the construction of a model of spatial (panel, longitudinal)

Table 1

Rating assessment of the fund of international migrants, employment in agriculture and the index of agricultural products of Europe, 2010–2021

Europe	On average, the fund of international migrants (0.00/% of the total population) by ranking 2010–2021	Average employment in agriculture, (% of employed) by ranking 2010–2021	Average agricultural product index (2014–2016=100) by ranking 2010–2021
Europe			
Eastern Europe	4	1	1
Western Europe	1	3	3
Northern Europe	2	4	3
Southern Europe	3	2	3

Source: calculated by the authors

Table 2

Grouping of macroeconomic indicators of states on the study of migration risks in the management of agribusinesses in Europe, 2010–2021.

Groups	Countries in the group according to the ranking	Years	Employment in agriculture (% of employed), Y	International Migrants Fund (0.00/% of the total population), X_1	Agricultural production index (2014–2016=100), X_2
1st group of Eastern European countries 1st place in the statistical sample of employment in agriculture, %	Ukraine, Moldova, Romania, Bulgaria, Hungary, Czech Republic, Slovakia, Poland	2010	11,70	6,50	81,00
		2011	11,72	6,48	81,30
		2012	11,74	6,46	81,60
		2013	11,76	6,44	81,90
		2014	11,78	6,42	82,20
		2015	9,80	6,70	98,00
		2016	10,49	6,58	93,13
		2017	10,22	6,60	95,65
		2018	9,96	6,63	98,16
		2019	9,69	6,65	100,68
		2020	9,42	6,67	103,19
		2021	8,40	7,10	107,00
2nd group of Southern European countries 2nd place in the statistical sample of employment in agriculture, %	Italy, Monaco, Malta, Greece, Spain, Portugal, Serbia, Montenegro, Croatia, Albania, Bosnia and Herzegovina, Slovenia	2010	7,60	10,60	101,00
		2011	7,45	10,58	100,96
		2012	7,30	10,56	100,92
		2013	7,15	10,54	100,88
		2014	7,00	10,52	100,84
		2015	6,90	10,30	101,00
		2016	6,73	10,35	100,89
		2017	6,59	10,30	100,88
		2018	6,45	10,25	100,87
		2019	6,30	10,20	100,86
		2020	6,16	10,15	100,85
		2021	6,10	11,60	100,00
3rd group of Western European countries 3rd place in the statistical sample of employment in agriculture, %	France, Belgium, Netherlands, Luxembourg, Germany, Austria, Liechtenstein, Switzerland	2010	2,40	12,80	96,00
		2011	2,43	12,83	96,20
		2012	2,46	12,86	96,40
		2013	2,49	12,89	96,60
		2014	2,52	12,92	96,80
		2015	2,10	13,50	101,00
		2016	2,28	13,40	99,87
		2017	2,25	13,51	100,64
		2018	2,21	15,11	101,41
		2019	2,18	15,22	102,18
		2020	2,14	15,34	102,95
		2021	1,80	16,90	97,00
4th group of Northern European countries 4th place in the statistical sample of employment in agriculture, %	Finland, Sweden, Norway, Denmark, Great Britain, Ireland, Iceland, Estonia, Lithuania, Latvia	2010	2,20	11,30	92,00
		2011	2,24	11,50	92,80
		2012	2,28	11,70	93,60
		2013	2,32	11,90	94,40
		2014	2,36	12,10	95,20
		2015	2,10	12,70	102,00
		2016	2,24	12,77	100,80
		2017	2,24	13,02	102,46
		2018	2,23	13,28	104,11
		2019	2,23	13,54	105,77
		2020	2,23	13,80	107,43
		2021	1,70	14,10	103,00

Source: calculated by the authors

Table 3

Determination of the average value of the indicator and factors for the study of migration risks in the management of European agro-industrial enterprises by groups, 2010–2021

Groups	Employment in agriculture (% of employed), y	International migrants fund (0.00/% of the total population), x_1	Agricultural production index (2014–2016=100), x_2
1	10,56	6,60	91,98
2	6,81	10,50	100,83
3	2,27	13,94	98,92
4	2,20	12,64	99,46

Source: calculated by the authors

data with fixed effects of migration risks in the management of agro-industrial enterprises in Europe for the forecast period using the same algorithm. Let us find the average for each variable of the model in the context of each group using the built-in mathematical function "average" of Microsoft Excel spreadsheets (Table 5).

We determine, as before, the personal effects of each group for the next forecast period. As a result of the calculations, we obtained coefficients:

b	-0,644
	-0,017

Consequently, because of the calculations, we have the predicted value of individual effects of migration risks in the management of agribusinesses in Europe for the next 2024–2026.

1st group of Eastern European states $a_1 = 14.14$;

2nd Group of Southern European States $a_2 = 14.11$;

3rd group of Western European states $a_3 = 14.16$;

4th Group of Nordic States $a_4 = 13.65$.

The obtained forecast results can be grouped, ranked and compared with preliminary calculations of individual effects (Table 6).

If we characterise and compare the obtained forecast values of individual effects and individual effects of previous years, we can conclude that the leader is the third group of Western European states ($a_3 = 14.16$). That is, migration movement and migration risks are possible in the states of Western Europe, which are more secure and stable.

Graphically, the forecasted values of individual effects in the study of migration risks in agribusiness management in Europe using spatial (panel, longitudinal) data models, 2024–2026 are presented in Fig. 3.

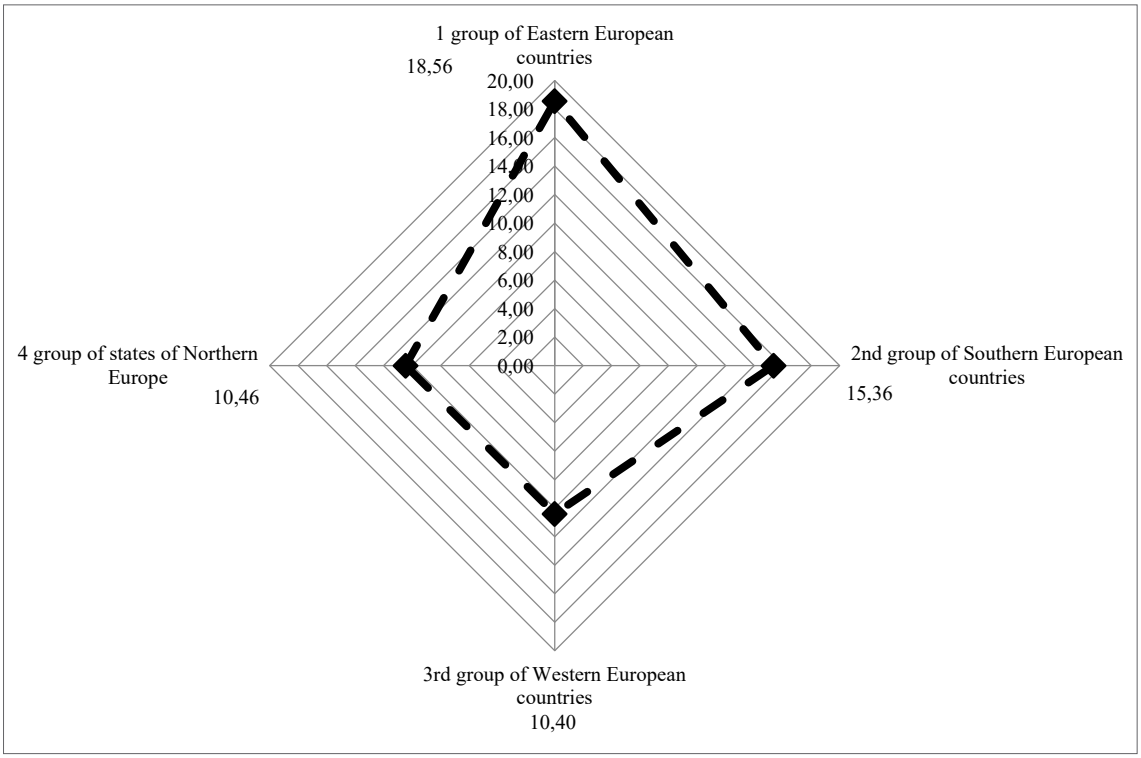

Figure 2. Graphical representation of individual effects in a study of migration risks in agribusiness management in Europe, 2010–2021

Source: calculated by the authors

Table 4

Forecasting employment in agriculture, the international migrant stock and the European agricultural product index, 2024–2026.

№ of the group	Years	Employment in agriculture (% of employed), Y	International migrants fund (0.00/% of the total population), X_1	Agricultural production index (2014–2016=100), X_2
1	2024	8,05	6,93	113,78
	2025	7,76	6,97	116,34
	2026	7,46	7,01	118,91
2	2024	5,62	10,57	100,46
	2025	5,48	10,58	100,42
	2026	5,34	10,59	100,37
3	2024	1,88	16,82	103,28
	2025	1,83	17,16	103,79
	2026	1,79	17,50	104,31
4	2024	2,00	14,84	111,56
	2025	1,98	15,10	112,98
	2026	1,96	15,36	114,41

Source: calculated by the authors

Table 5

Determination of the mean value of the main factors in predicting migration risks in agribusiness management in Europe, 2024–2026

Group	Employment in agriculture (% of employed), y	International migrants fund (0.00/% of the total population), x_1	Agricultural production index (2014–2016=100), x_2
1	4,26	12,45	108,38
2	3,10	14,28	105,73
3	1,91	16,13	108,39
4	1,98	15,10	112,98

Source: calculated by the authors

Table 6

The results of individual effects in the study and forecasting of migration risks in the management of agricultural enterprises in Europe and their ranking, 2010–2021, 2024–2026

Group of countries	Symbolic designation	Individual effects in the study of migration risks in the management of agricultural enterprises in Europe, 2010–2021	Ranking of the indicator by the built-in statistical function "rank", 2010–2021.
1st group of Eastern European countries	a_1	18,56	1
2nd group of Southern European countries	a_2	15,36	2
3rd group of Western European countries	a_3	10,40	4
4th group of Northern European countries	a_4	10,46	3

Source: calculated by the authors

Thus, modelling the impact of migration risks is an urgent issue in the management of agro-industrial enterprises in Europe. Our research has shown the importance and necessity of using spatial (panel, longitudinal) data models in the process of analysing migration phenomena and their forecasting. These models provide an opportunity for a more comprehensive and accurate account of complex economic processes at different levels (macro-, meso- and micro-levels). The use of spatial data models makes it possible to avoid geographical and regional factors, uncertainty and unpredictability in economic processes. These models allow analysis, comparison and forecasting of economic activity at different levels from individual companies to entire regions and countries. Thus, the use of panel, longitudinal

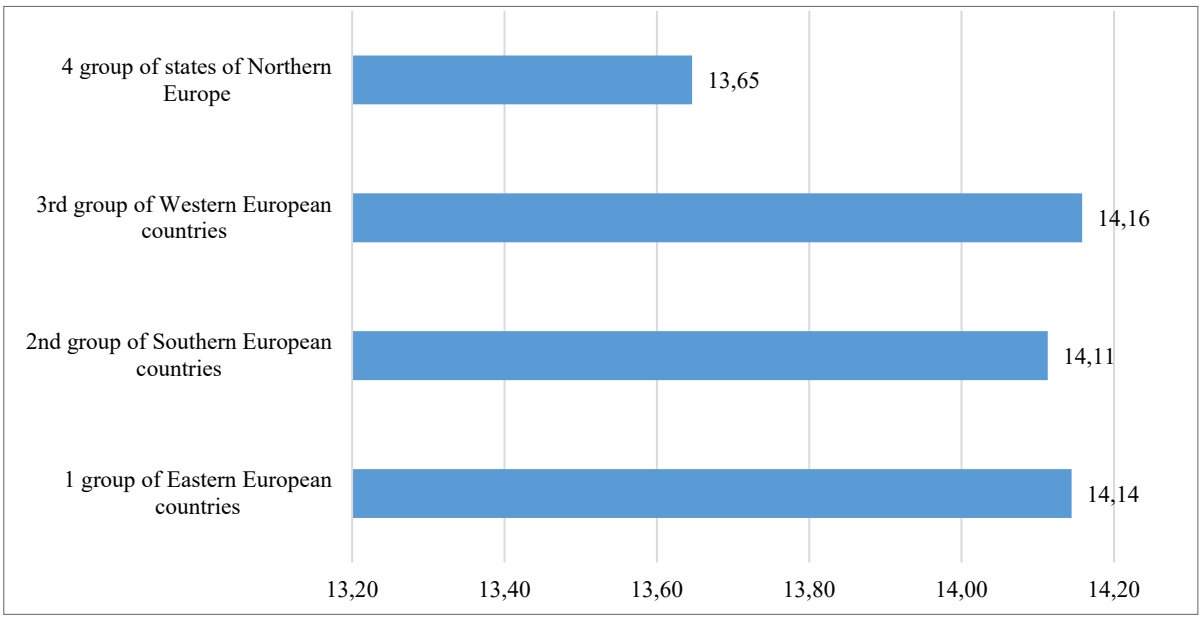

Figure 3. Forecasting individual effects in a study of migration risks in agribusiness management in Europe, 2024–2026.

Source: calculated by the authors

spatial data models is a tool for public authorities, scientists and scholars in planning and implementing regional and state migration policy, which is of great importance for sustainable social and economic development.

Conclusions. Migration has an indisputable impact on the effective development of agro-industrial enterprises. An important measure is the prevention of migration risks, possibly in the process of effective management of agro-industrial enterprises. An effective measure of such management is modelling the impact of migration risks on agricultural enterprises. Considering this, the article proposes measures for modelling the impact of migration risks on agribusinesses in Europe. It is determined that it is important to consider migration in the context of a specific geographical and socio-cultural situation, as well as to take into account the positive and negative aspects of agriculture and rural areas. It was proposed to use panel or longitudinal data of social and economic processes to model the impact. These models made it possible to differentiate geographical and socio-cultural features of migration more fully and accurately, which is an important step for regional development planning. In the example of migration processes in Europe for the last 2010–2021, the greatest migration risks for agribusinesses were identified. It has been determined that by the coefficient of individual effect of migration processes management in agro-industrial enterprises in Europe, the leader is the 1st group of Eastern European states (with the indicator 18.56). The lowest indicator is in the third group of Western European states (10,40 respectively). The process of forecasting migration risks in the management of agro-industrial enterprises in Europe is important to realise. If we characterise and compare the forecast values of individual effects and individual effects of previous years obtained by us, we can conclude that the leader is the third group of Western European states (with the indicator — $a_3 = 14.16$). In such a context, it is possible migration movement and migration risks in the countries of Western Europe, which are more secure and stable. Modelling migration risks in the management of agro-industrial enterprises in Europe proved that there is a need for a systematic analysis of the mentioned processes. In particular, the instability of the institutional and market environment in European countries causes constant changes in migration trends and, consequently, changes in the impact of migration risks on agribusinesses. In this context, there is a need for an uninterrupted analysis of migration risks in the management of European agribusinesses. Our next research will focus on the regulation of employment among labour migrants in crisis and military conflict conditions.

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АНАЛІЗ МІГРАЦІЙНИХ РИЗИКІВ В УПРАВЛІННІ АГРОПРОМИСЛОВИМИ ПІДПРИЄМСТВАМИ ЄВРОПИ

Анотація. *Без трудових ресурсів неможливо уявити ефективне функціонування агропромислових підприємств будь-якої країни світу. Необхідно враховувати, що на це час у світі існує нерівномірний демографічний розподіл, а міграція в умовах глобалізації набула значних масштабів. Без трудових мігрантів деякі сільськогосподарські галузі зазнають колапс. Одночасно мігранти здатні підсилювати ризики та знижувати ефективність розвитку агросектору. Важливо вчасно здійснювати моніторинг міграційних ризиків та приймати необхідні управлінські рішення з метою сталого розвитку агропромислових підприємств.*

Джерельною базою слугували статистичні дані основних показників міграційних процесів Європи, зокрема в географічному розрізі: Східна, Західна, Північна та Південна Європа, за останні 2010–2021 рр. При аналізі міграційних ризиків в управлінні агропромисловими підприємствами Європи використано методи індукції, дедукції, аналізу, синтезу, математичного моделювання, статистичного аналізу просторових (панельних, лонгітюдних) даних.

Результати аналізу міграційних ризиків в управлінні агропромисловими підприємствами Європи засвідчили, що за коефіцієнтом індивідуального ефекту управління міграційними процесами лідером є група держав Східної Європи, аутсайдерами країни Західної Європи. Якщо характеризувати та порівнювати отримані прогнозні значення індивідуальних ефектів та індивідуальні ефекти попередніх років, то можна зробити висновок, що лідером є група держав Західної Європи. Зазначене свідчить про високу можливість міграційного переміщення та міграційних ризиків в державах Західної Європи, які є більш забезпеченими та стабільними.

Моделювання міграційних ризиків в управлінні агропромисловими підприємствами Європи довело, що існує потреба систематичного аналізу зазначених процесів. Зокрема нестабільність інституціонального та ринкового середовища в країнах Європи обумовлюють постійну зміну міграційних тенденцій та, відповідно, зміну впливу на агропідприємства міграційних ризиків. Даний аналіз має практичне значення в управлінській діяльності, з метою вчасного ухвалення рішення та попередження негативних наслідків міграційних ризиків.

Ключові слова: *міграційні ризики, управління, агропромислові підприємства, робоча сила, зайнятість, мігранти, сільськогосподарська продукція*

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ECONOMIC AND SIMULATION MODELLING OF SCENARIOS OF CHANGES IN MIGRATION MOVEMENTS OF THE POPULATION

Abstract. *The population of any country is constantly changing. Its movement or dynamics depends on many factors that can have both negative and positive consequences for the movement of the population. An important aspect of controlling population movements by the state or other interested market participants is continuous monitoring of its changes. Such monitoring will enable analysis of the cause-and-effect relationships of dynamic changes in population migration and identify effective migration policy options.*

To monitor changes in the migration movement of the population, a system of methods and tools was used that are appropriate for the study. In particular, the main methods used include: simulation modelling, regression analysis, Microsoft Excel spreadsheet tools and forecasting with the creation of 5 scenarios. The information source of the study was the data from the State Statistics Service of Ukraine. A methodology for assessing the migration movement of the population by type of area, including interstate migration movement, is proposed. To forecast migration movement, the coefficients of dynamic regression models are determined, and a system of statistical functions is calculated. The optimal balance of migration is determined in the course of simulation scenario modelling. The tendency to increase the share of the rural population from 15.73% to 20.03% and decrease the share of the urban population from 84.27% to 79.97% in the forecast year 2024 is determined.

The developed methodology of economic and simulation modelling of scenarios of changes in the movement of the population will allow the making of correct managerial decisions in the context of complex institutional systems and crisis phenomena. The methodology will be useful for representatives of public authorities and all interested market participants involved in monitoring migration movements.

Keywords: *migration, population, simulation modelling, scenarios, forecasting, simulation modelling, regression analysis*

1. Introduction

Population migration involves the movement of people within or outside a country. Such movement exists in every country, but its dynamics and trends depend on the socio-economic development and political or security situation in the country. Simulation modelling of population migration is an important aspect of strategizing, managing state and regional policies and is extremely important in times of economic or social crises. Forecasting migration helps public managers understand what human or labour resources will be available in a particular area and what trends will influence demographic change. Modelling is especially important in the process of state planning of the workforce needed to balance the labour market, create infrastructure, protect migrants, reduce interethnic conflicts and solve problems with the even distribution of resource potential. Economic simulation modelling is important for modern Ukraine, whose economy is characterised by the trends of population ageing, declining birth rates and emigration of highly qualified specialists. The results of effective migration modelling will facilitate the adaptation of Ukraine's regions to changes in the globalised labour market and increased competition for skilled workers.

The article is aimed at developing a methodology for economic simulation modelling of changes in the migration movement of the population of Ukraine. Each author researched interesting and relevant aspects of migration in his or her view.

As an example, Bu *et al.,* [1], assessed the impact of energy consumption and carbon emissions on population migration in China. Using the Durbin model, the authors conducted a thorough spatial econometric study on the activities of 30 provincial regions of China from 2000 to 2019 and focused on the intensification of emission reduction policies. The results of the article are presented in the form of two matrices that reflect the cause-and-effect relationships of population displacement.

Jeanty *et al.,* [2], analysed the movement of the population depending on the dynamics of housing prices. The authors focused on the migration of the population of Michigan and found out how the increase in housing costs makes the labour force move to areas with lower rental costs.

Chen *et al.,* [3], determined how the COVID-19 epidemic has affected population migration. The article develops a mathematical model of the spread of the coronavirus according to population migration and identifies how the movement of people contributes to the spread of the infection. The developed model made it possible to determine the dynamics of infectious disease transmission in the process of population migration, as well as to identify strategies to prevent the spread of COVID-19.

Gu *et al.,* [4], determined how the internal migration of older people in China affects the healthcare sector. By calculating the gravity model of the Poisson pseudo-maximum likelihood (PPML), the authors found that the quantity and quality of healthcare services have an impact on the migration of older people. Thus, there is an increased need to adapt healthcare policy to China's urbanisation.

Guo *et al.,* [5], analysed the impact of air pollution on population migration in China. The researchers determined the dynamics of the labour force in China and found that: population movement in Chinese regions demonstrates sensitivity to air pollution; population migration was more pronounced among women, middle-aged people, people with lower levels of education, etc.

Many authors have developed methodologies, tools and stages of economic and simulation modelling of various economic processes, which should be partially adapted to our study [6–12]. Relevant for us is the study by Stange *et al.,* [13], which analyses migration in Southeast Asian countries from 2013 to 2018. The researchers used a system of adaptive tools and methods for researching migration, which are appropriate for use in our study.

Tasker and Braam, [14], examined the link between forced migration and zoonotic diseases. The article presents the results of an analysis of eight electronic databases: ProQuest, SCOPUS, Web of Science, PubMed, PLoSOne, Science Direct, JSTOR, and Google Scholar to identify articles on the spread of infections among forced migrants. The authors' thorough work with literary sources is noteworthy, which helped them to solve the main tasks of their research. Mouazen and Hernбndez-Lara, [15], studied the dependence of internal and external migration on the sustainable development of regions and smart cities. The authors determined that effective socio-economic development of territories and high business activity contribute to the migration of people to highly developed or innovatively active territories. While noting the importance and relevance of the above-mentioned works of scholars, we note that it is necessary to dwell in more detail on modelling scenarios of changes in the migration movement of the population to support systematic monitoring of the population movement in Ukraine.

2. Materials and Methods

To model the scenarios of changes in migration movement, we used simulation modelling, regression analysis, Microsoft Excel spreadsheet tools, built-in mathematical and statistical functions, and the Analysis add-in (analysis of the "What if?" type → Scenario Manager) of the spreadsheet processor. The data of the interval dynamic series of migration movement of the population by type, including interstate migration movement, 2002–2021, were obtained from the official source of the State Statistics Service of Ukraine.

The adequacy and further forecasting of the resultant indicator of dynamic regression models was checked using Fisher's F test. The coefficients of dynamic regression models, built-in statistical

Table 1

Dynamics of migration movement of the population by type of area, 2002–2021

Years	All flows		Including interstate migration	
	number of arrivals	number of dropouts	number of arrivals	number of dropouts
Urban and rural areas				
2002	22465	24213	448	1687
2003	21613	23769	310	1711
2004	20586	22786	299	968
2005	20660	22938	298	1069
2006	21898	23705	337	914
2007	22425	24396	314	898
2008	19588	21460	388	654
2009	18989	20456	313	448
2010	19551	20726	196	273
2011	18460	20259	221	246
2012	19585	20987	295	206
2013	18773	19679	441	196
2014	18897	19052	480	378
2015	19812	20594	332	346
2016	7629	7882	154	117
2017	15214	17041	152	702
2018	22000	24198	341	1227
2019	18563	21037	341	1320
2020	14462	15579	202	279
2021	15656	16991	330	459
Urban areas				
2002	13066	14332	224	958
2003	12836	14232	176	921
2004	12845	13601	181	537
2005	13146	13120	177	554
2006	13760	13773	210	412
2007	13919	14202	189	484
2008	11898	12414	231	317
2009	11399	11547	145	260
2010	11507	12147	125	159
2011	10695	11717	108	134
2012	11173	12570	181	113
2013	10799	12007	285	110
2014	10736	11730	267	172
2015	10388	12686	192	153
20161	3336	4783	104	44
20171	8238	9958	92	391
2018	12634	13748	256	791
2019	11100	11927	221	687
2020	8260	8916	101	128
2021	9103	10228	202	258
Rural areas				
2002	9399	9881	224	729
2003	8777	9537	134	790
2004	7741	9185	118	431
2005	7514	9818	121	515
2006	8138	9932	127	502
2007	8506	10194	125	414
2008	7690	9046	157	337

Continuation of table 1

2009	7590	8909	168	188
2010	8044	8579	71	114
2011	7765	8542	113	112
2012	8412	8417	114	93
2013	7974	7672	156	86
2014	8161	7322	213	206
2015	9424	7908	140	193
20161	4293	3099	50	73
20171	6976	7083	60	311
2018	9366	10450	85	436
2019	7463	9110	120	633
2020	6202	6663	101	151
2021	6553	6763	128	201

Source: https://www.ukrstat.gov.ua/

functions MAX, MIN, GROWTH, EXP, TREND and LN were used to forecast the migration movement of the population by type of area, including interstate migration movement. In order to achieve the goal of the study, scenario forecasting was used to create 5 scenarios: pessimistic forecast; realistic forecast; optimistic forecast; forecast (forecasting migration movement by the nonlinear function GROWTH) and forecast (forecasting migration movement by mathematical functions) to determine the balance of migration movement of the population.

Taking into account the above, we will analyse and forecast by simulation modelling using a dynamic series of migration movements of population by type, including interstate migration movement during 2002–2021 and for the next 2024.

To research, analyse and forecast this indicator, we use Microsoft Excel spreadsheets, built-in mathematical and statistical functions, and the Analysis add-in ("What if..." → Scenario Manager) of the spreadsheet processor.

The data of the interval dynamic series of the migration movement of the population by type, including interstate migration movement, 2002–2021 are presented in Table 1.

Analysing the interval dynamic series, it is worth noting fluctuations in migration movements by type of area, including interstate migration movements over the period 2002–2021.

3. Results and Discussion

We will calculate statistical indicators for further simulation modelling, analysis and forecasting of migration movement of the population by type of area, including interstate migration movement, using Microsoft Excel spreadsheets and built-in mathematical and statistical functions LINEST and FINV (Table 2).

In general, the dynamic regression model has the following form:

$$y = a_0 + a_1 x \quad (1)$$

where a_1, a_0 are the parameters of the dynamic regression model;

x is the time period factor, in our study 2002–2021.

Further, as a result of processing statistical data on the migration movement of the population by type of area, including interstate migration movement over the past 20 years, we have the main performance coefficients: regression, determination, and the calculated value of the Fisher's F criterion. In our study of the migration movement of the population by type of area, including interstate migration movement over the past 20 years, dynamic regression models are qualitative and adequate, and we continue to forecast them.

To forecast the migration movement of the population by type of area, including interstate migration movement, we use the coefficients of dynamic

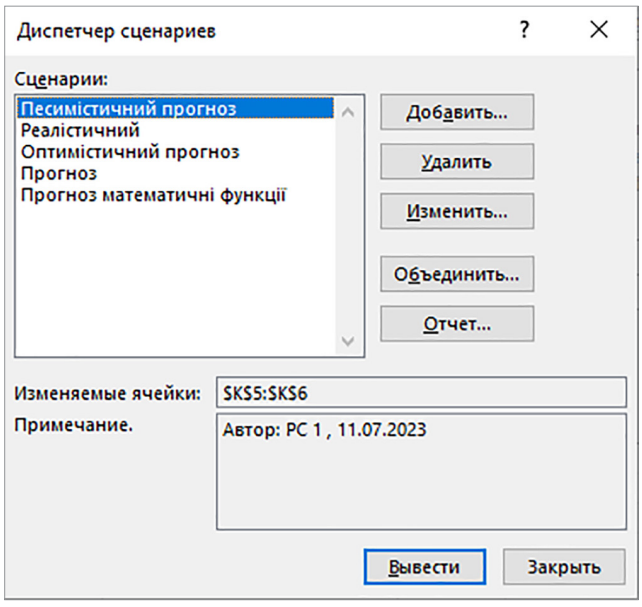

Figure 1. Listing of applications for using the Analysis add-in ("What if?" → Scenario Manager) of Microsoft Excel spreadsheets to determine the balance of migration movement, 2024

Source: listing of the application using the Microsoft Excel Spreadsheet Analysis add-in

Table 2

Results of statistical processing of dynamic indicators of migration movement of the population by type of area, including interstate migration movement, 2002–2021

Dynamic regression function of migration movement of the population	Parameters of regression		Coefficient of determination R^2	Calculated value of Fisher's F criterion, F_{calc}	Tabulated value of Fisher's F criterion, F_{table}	Standard deviation
	a_1	a_0				
Dynamic regression model of migration movement of the population by the number of arrivals by type of area (urban and rural), (persons)						
$y = 22556{,}97 - 353{,}87x$	-353,87	22556,97	0.36	10,19	1,01	110,84
Dynamic regression model of migration movement of the population by the number of out-migrants by type of area (urban and rural), (persons)						
$y = 24522{,}09 - 393{,}78x$	-393,78	24522,09	0,36	10,12	1,01	123,80
Dynamic regression model of migration movement of the population by the number of people arriving in urban areas, (persons)						
$y = 13863{,}79 - 268{,}75x$	-268,75	13863,79	0,42	13,16	1,01	74,09
Dynamic regression model of migration movement of the population by the number of people leaving urban areas, (persons)						
$y = 14419{,}62 - 232{,}16x$	-232,16	14419,62	0,38	10,81	1,01	70,62
Dynamic regression model of migration movement of the population by the number of newcomers to rural areas, (persons)						
$y = 8693{,}18 - 85{,}12x$	-85,12	8693,18	0,18	3,88	1,01	43,19
Dynamic regression model of migration movement of the population by the number of people leaving rural areas, (persons)						
$y = 10102{,}47 - 161{,}62x$	-161,62	10102,47	0,32	8,40	1,01	55,75
Dynamic regression model of interstate migration movement of population by the number of arrivals by type of area (urban and rural), (persons)						
$y = 349{,}96 - 3{,}84x$	-3,84	349,96	0,06	1,20	1,01	3,51
Dynamic regression model of the interstate migration movement of the population by the number of out-migrants by type of area (urban and rural), (persons)						
$y = 1119{,}22 - 39{,}46x$	-39,46	1119,22	0,22	5,08	1,01	209,81
Dynamic regression model of the interstate migration movement of the population by the number of people arriving in urban areas, (persons)						
$y = 193{,}13 - 0{,}93x$	-0,93	193,13	0,01	0,17	1,01	26,96
Dynamic regression model of the interstate migration movement of the population by the number of people leaving urban areas, (persons)						
$y = 595{,}44 - 20{,}60x$	-20,60	595,44	0,19	4,12	1,01	121,56
Dynamic regression model of the interstate migration movement of the population by the number of newcomers to rural areas, (persons)						
$y = 156{,}83 - 2{,}91x$	-2,91	156,83	0,15	3,24	1,01	19,38
Dynamic regression model of the interstate migration movement of the population by the number of people leaving rural areas, (persons)						
$y = 523{,}77 - 18{,}86x$	-18,86	523,77	0,25	6,11	1,01	91,43

Source: calculated by the authors

regression models, and built-in statistical functions MAX, MIN, GROWTH, EXP, TREND and LN. Thus, the results of the calculations provide forecast values of the migration movement of the population by type of area, including interstate migration movement for 2024 (Table 3).

Having obtained the projected values of migration movement of the population by type of area, including interstate migration movement, in 2024, we proceed to the method of simulation modelling to determine the balance of migration movement of the population and determine its best optimal result. As before, to calculate the balance of migration movement of the population by the method of simulation modelling, we use Microsoft Excel spreadsheets with the Analysis add-in ("What if?" → Scenario Manager).

In our study, we created 5 scenarios (pessimistic forecast, realistic forecast, optimistic forecast, forecast (forecasting migration movement by the nonlinear GROWTH function) and forecast (forecasting migration movement by mathematical functions) to determine the balance of migration movement of the population (Fig. 1)

The results of the simulation modelling are the results of the balance of migration movement of the population for the forecast year 2024 (Table 4).

Table 3

Forecasting migration movement of the population by type of area, including interstate migration movement, 2024

Flows	Initial data, 2021	Forecasting the migration movement of the population in urban and rural areas				
		Pessimistic forecast (functions MAX, MIN)	Realistic forecast of dynamic series (production function)	Optimistic forecast (MIN, MAX function)	Forecast (nonlinear GROWTH function)	Forecast (mathematical functions)
number of arrivals, in persons	15656	7629	14418	22465	14135	14135
number of leavers, in persons	16991	24396	15465	7882	15149	15149
Flows	Initial data, 2021	Forecasting the migration movement of the urban population				
		Pessimistic forecast (functions MAX, MIN)	Realistic forecast of dynamic series (production function)	Optimistic forecast (MIN, MAX function)	Forecast (nonlinear GROWTH function)	Forecast (mathematical functions)
number of arrivals, in persons	9103	3336	7683	13919	7525	7525
number of leavers, in persons	10228	14332	9080	4783	8926	8926
Flows	Initial data, 2021	Forecasting the migration movement of the rural population				
		Pessimistic forecast (functions MAX, MIN)	Realistic forecast of dynamic series (production function)	Optimistic forecast (MIN, MAX function)	Forecast (nonlinear GROWTH function)	Forecast (mathematical functions)
number of arrivals, in persons	6553	4293	6735	9424	6594	6594
number of leavers, in persons	6763	10450	6385	3099	6208	6208
Flows	Initial data, 2021	Forecasting interstate migration movement of urban and rural areas population				
		Pessimistic forecast (functions MAX, MIN)	Realistic forecast of dynamic series (production function)	Optimistic forecast (MIN, MAX function)	Forecast (nonlinear GROWTH function)	Forecast (mathematical functions)
number of arrivals, in persons	330	152	312	480	243	243
number of leavers, in persons	459	1711	262	117	262	262
Flows	Initial data, 2021	Forecasting the interstate migration movement of the urban population				
		Pessimistic forecast (functions MAX, MIN)	Realistic forecast of dynamic series (production function)	Optimistic forecast (MIN, MAX function)	Forecast (nonlinear GROWTH function)	Forecast (mathematical functions)
number of arrivals, in persons	202	92	192	285	154	154
number of leavers, in persons	258	958	142	44	131	131
Flows	Initial data, 2021	Forecasting the interstate migration movement of the rural population				
		Pessimistic forecast (functions MAX, MIN)	Realistic forecast of dynamic series (production function)	Optimistic forecast (MIN, MAX function)	Forecast (nonlinear GROWTH function)	Forecast (mathematical functions)
number of arrivals, in persons	128	50	90	224	87	87
number of leavers, in persons	201	790	188	73	127	127

Source: calculated by the authors

Table 4

Results of simulated modeling of the values of the balance of the population migration movement performed by the tool Analysis → Manager of Microsoft Excel spreadsheet scenarios, 2024

Stage 1

Scenario structure		Current values (Initial data, 2021)	Pessimistic forecast	Realistic forecast	Optimistic forecast	Forecast (nonlinear GROWTH function)	Forecast mathematical functions
			Calculated by the Scenario Manager, 11.07.2023	Calculated by the Scenario Manager, 11.07.2024	Calculated by the Scenario Manager, 11.07.2025	Calculated by the Scenario Manager, 11.07.2026	Calculated by the Scenario Manager, 11.07.2027
Variable:							
	K5	15656	7629	14418	22465	14135	14135
	K6	16991	24396	15465	7882	15149	15149
Result:							
	K7	-1335	-16767	-1047	14583	-1014	-1014
Flows		Initial data, 2021 p.	Forecasting the migration movement of the population of urban and rural areas				
			Pessimistic forecast (functions MAX, MIN)	Realistic forecast of dynamic series (production function)	Optimistic forecast (MIN, MAX function)	Forecast (nonlinear GROWTH function)	Forecast (mathematical functions)
balance of migration movement of the population, persons		-1335	-16767	-1047	14583	-1014	-1014

Stage 2

Scenario structure		Current values (Initial data, 2021)	Pessimistic forecast	Realistic forecast	Optimistic forecast	Forecast (nonlinear GROWTH function)	Forecast mathematical functions
			Calculated by the Scenario Manager, 11.07.2023	Calculated by the Scenario Manager, 11.07.2024	Calculated by the Scenario Manager, 11.07.2025	Calculated by the Scenario Manager, 11.07.2026	Calculated by the Scenario Manager, 11.07.2027
Variables:							
	K25	9103	3336	7683	13919	7525	7525
	K26	10228	14332	9080	4783	8926	8926
Result:							
	K27	-1125	-10996	-1397	9136	-1401	-1401
Flows		Initial data, 2021	Forecasting the migration movement of the urban population				
			Pessimistic forecast (functions MAX, MIN)	Realistic forecast of dynamic series (production function)	Optimistic forecast (MIN, MAX function)	Forecast (nonlinear GROWTH function)	Forecast (mathematical functions)
Balance of migration movement of the population, persons		-1125	-10996	-1397	9136	-1401	-1401

Stage 3

Scenario structure	Current values (Initial data, 2021)	Pessimistic forecast	Realistic forecast	Optimistic forecast	Forecast (nonlinear function GROWTH)	Forecast mathematical functions
		Calculated by the Scenario Manager, 11.07.2023	Calculated by the Scenario Manager, 11.07.2024	Calculated by the Scenario Manager, 11.07.2025	Calculated by the Scenario Manager, 11.07.2026	Calculated by the Scenario Manager, 11.07.2027

Variables:							
	K43	6553	4293	6735	9424	6594	6594
	K44	6763	10450	6385	3099	6208	6208
Result:							
	K45	-210	-6157	350	6325	386	386
Flows		Initial data, 2021	Forecasting the migration movement of the rural population				
			Pessimistic forecast (functions MAX, MIN)	Realistic forecast of dynamic series (production function)	Optimistic forecast (MIN, MAX function)	Forecast (nonlinear GROWTH function)	Forecast (mathematical functions)
balance of migration movement of the population, persons		-210	-6157	350	6325	386	386

Stage 4

Scenario structure		Current values (Initial data, 2021)	Pessimistic Forecast	Realistic Forecast	Optimistic forecast	Forecast nonlinear function	Forecast mathematical functions
			Calculated by the Scenario Manager, 11.07.2023	Calculated by the Scenario Manager, 11.07.2024	Calculated by the Scenario Manager, 11.07.2025	Calculated by the Scenario Manager, 11.07.2026	Calculated by the Scenario Manager, 11.07.2027
Variables:							
	K5	330	152	312	480	243	243
	K6	459	1711	262	117	262	262
Result:							
	K7	-129	-1559	50	363	-19	-19
Flows		Initial data, 2021	Forecasting the interstate migration movement of urban and rural population				
			Pessimistic forecast (functions MAX, MIN)	Realistic forecast of dynamic series (production function)	Optimistic forecast (MIN, MAX function)	Forecast (nonlinear GROWTH function)	Forecast (mathematical functions)
balance of migration movement of the population, persons		-129	-1559	50	363	-19	-19

Stage 5

Scenario structure		Current values (Initial data, 2021)	Pessimistic forecast	Realistic forecast	Optimistic forecast	Forecast (nonlinear GROWTH function)	Forecast mathematical functions
			Calculated by the Scenario Manager, 11.07.2023	Calculated by the Scenario Manager, 11.07.2024	Calculated by the Scenario Manager, 11.07.2025	Calculated by the Scenario Manager, 11.07.2026	Calculated by the Scenario Manager, 11.07.2027
Variables:							
	K25	202	92	192	285	154	154
	K26	258	958	142	44	131	131
Result:							
	K27	-56	-866	50	241	23	23
Flows		Initial data, 2021	Forecasting the interstate migration movement of the urban population				
			Pessimistic forecast (functions MAX, MIN)	Realistic forecast of dynamic series (production function)	Optimistic forecast (MIN, MAX function)	Forecast (nonlinear GROWTH function)	Forecast (mathematical functions)
balance of migration movement of the population, persons		-56	-866	50	241	23	23

Stage 6

Scenario structure		Current values (Initial data, 2021)	Pessimistic forecast	Realistic forecast	Optimistic forecast	Forecast (nonlinear GROWTH function)	Forecast mathematical functions
			Calculated by the Scenario Manager, 11.07.2023	Calculated by the Scenario Manager, 11.07.2024	Calculated by the Scenario Manager, 11.07.2025	Calculated by the Scenario Manager, 11.07.2026	Calculated by the Scenario Manager, 11.07.2027
Variables:							
	K43	128	50	90	224	87	87
	K44	201	790	188	73	127	127
Result:							
	K45	-73	-740	-98	151	-40	-40
Flows		Initial data, 2021	Forecasting the interstate migration movement of the rural population				
			Pessimistic forecast (functions MAX, MIN)	Realistic forecast of dynamic series (production function)	Optimistic forecast (MIN, MAX function)	Forecast (nonlinear GROWTH function)	Forecast (mathematical functions)
balance of migration movement of the population, persons		-73	-740	-98	151	-40	-40

Source: calculated by the authors

** Notes: The "Current Values" column represents the values of the cells that are changing at the time the Scenario Summary Report is generated. Cells that are changing for each scenario are highlighted in grey.*

Table 5

Optimal regression models for the study of migration movements and migration balance, 2024

Regression models for studying the migration movement of the population	The balance of migration movement of the population, persons
Forecasting the migration movement of the population in urban and rural areas	
Forecast (nonlinear GROWTH function)	-1014
Forecasting the migration movement of the urban population	
Realistic forecast of time series (production function)	-1397
Forecasting the migration movement of the rural population	
Realistic forecast of time series (production function)	350
Forecasting interstate migration movement of population urban and rural areas	
Forecast (nonlinear GROWTH function)	-19
Forecasting the interstate migration movement of the urban population	
Forecast (mathematical functions)	23
Forecasting the interstate migration movement of the rural population	
Forecast (nonlinear GROWTH function)	-40

Source: proposed by the authors

Further, based on the results of simulation modelling of the forecast values of the balance of migration movement of the population performed by the Analysis→ Scenario Manager of Microsoft Excel spreadsheets, we select the best regression models with the optimal value of the studied indicator, i.e. the balance of migration movement of the population (Table 5).

In the course of simulation modelling using the Scenario Manager, the optimal balance of migration was determined. More optimistic forecasts of the migration balance can be traced. However, their value from the scenario result was chosen to be close to the actual (current) value. After all, a sharp fluctuation in the value of the migration balance may vary and not correspond to real conditions.

4. Conclusions

To conclude the study, a pie chart is presented to illustrate the results, showing the balance of migration movement of urban and rural populations in 2021 and the forecast for 2024, as well as this

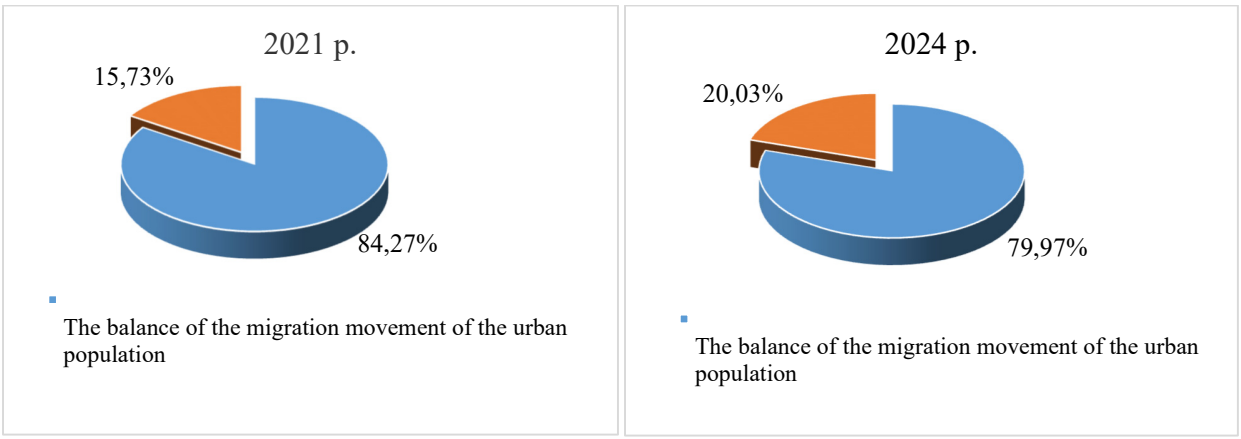

Figure 2. Balance of migration movement of urban and rural population, 2021, 2024.
Source: proposed by the authors

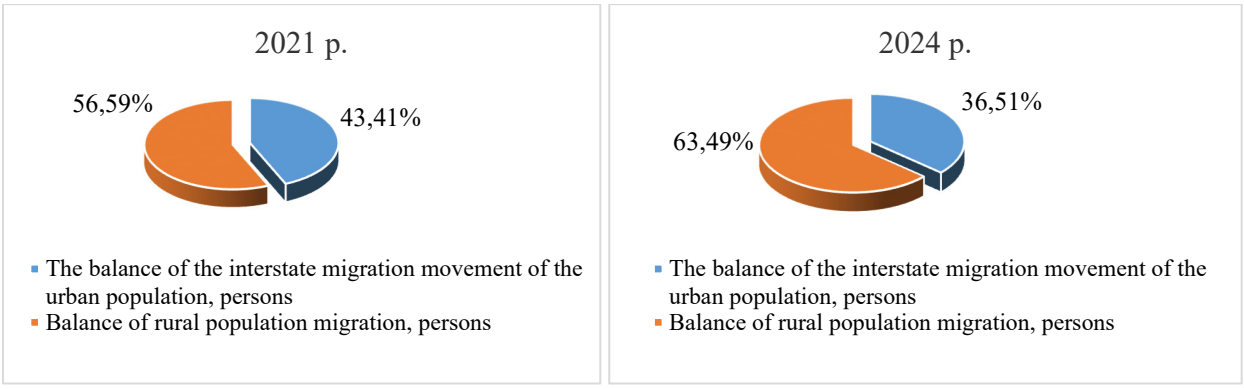

Figure 3. Balance of interstate migration movement of urban and rural population, 2021, 2024
Source: proposed by the authors

indicator of interstate migration movement for the same period.

Comparing the obtained graphical representations of the migration balance in the base year 2021 and the projected year 2024, it should be noted that in the projected year 2024, the share of the rural population will increase from 15.73% to 20.03% and the share of the urban population will decrease from 84.27% to 79.97%. Regarding the balance of interstate migration movement of urban and rural populations, the percentage of interstate migration balance of the rural population also increases from 56.59% in 2021 to 63.49%, while the urban population, on the contrary, is declining from 43.41% in 2021 to 36.51%.

Thus, simulation modelling plays an important role in statistical observations and forecasts of socio-economic phenomena. Economic and simulation modelling of scenarios of changes in the migration movement of the population allows us to make correct managerial decisions in the conditions of complex institutional systems and crisis phenomena.

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ЕКОНОМІКО-ІМІТАЦІЙНЕ МОДЕЛЮВАННЯ СЦЕНАРІЇВ ЗМІН МІГРАЦІЙНОГО РУХУ НАСЕЛЕННЯ

Анотація. *Населення будь-якої країни постійно змінюється. Його рух або динаміка залежить від багатьох чинників, які можуть мати як негативні так і позитивні наслідки для переміщення населення. Важливим аспектом контролю руху населення з боку державних або інших зацікавлених учасників ринку є безперервний моніторинг його змін. Такий моніторинг наддасть можливість проаналізувати причинно-наслідкові зв'язки динамічних змін в міграції населення та визначити ефективні шляхи міграційної політики.*

Для моніторингу змін міграційного руху населення використано систему методів та інструментів, які є доцільними в межах дослідження. Зокрема до основних використаних методів слід віднести: метод імітаційного моделювання, регресійного аналізу, інструментарій електронних таблиць Microsoft Excel, прогнозування зі створенням 5 сценаріїв. Інформаційним джерелом дослідження слугували данні Державної служби статистики України.

Запропоновано методику оцінювання міграційного руху населення за типом місцевості, в тому числі міждержавного міграційного руху. Для прогнозування міграційного руху визначено коефіцієнти динамічних регресійних моделей, розраховано систему статистичних функцій. В ході імітаційного сценарного моделювання визначено оптимальне сальдо міграції. Визначено тенденцію збільшення в прогнозному 2024 р. частки сільського населення з 15,73% до 20,03% та зменшення частки міського населення з 84,27% до 79,97%.

Розроблена методика економіко-імітаційного моделювання сценаріїв змін міграційного руху населення дозволить вірно ухвалювати управлінські рішення в умовах складних інституціональних систем і кризових явищ. Методика буде корисною для представників органів державної влади та усіх зацікавлених учасників ринку, які опікуються моніторингом міграційного руху населення.

Ключові слова: *міграція, населення, імітаційне моделювання, сценарії, прогнозування, імітаційне моделювання, регресійний аналіз*

JEL: C58; D2; G17

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FORECASTING CURRENT ASSETS OF ENTERPRISES TO SUPPORT FINANCIAL AND ECONOMIC SECURITY AND PREVENT BANKRUPTCY

Abstract. *Current assets are an important part of the operational activity of any business entity and are of key importance in maintaining the financial and economic security of the enterprise. Current assets of the enterprise have a significant impact on production activity, innovation, competitiveness, personnel, logistics, etc. They help to avoid interruptions in production and effectively commercialize innovative products on the market. It is impossible to form effective financial and economic policies and concepts of innovative development of the enterprise without taking into account current assets. Thus, there is a conceptual need to develop a methodology for forecasting the company's current assets, which will ensure the support of financial and economic security and prevent bankruptcy.*

The information resource for our research was the reported data of JSC "Poltavaholod", TM "Kozub Product", LLC "Reshetylivskiy Maslozavod", LLC "Lubensky Dairy Plant" (trademark "Harmony") and LLC "Orzhitskyi Molokozavod" (trademark "Zarog") for the period 2018–2022. In order to understand the theoretical essence of the financial stability of the enterprise, we deeply studied the information resource regarding the legislative regulation of the bankruptcy procedure. In order to reveal the topic of the article, we used a system of statistical and economic-mathematical methods.

The results of the modeling of the forecasting of the current assets of enterprises proved that the largest projected increase in the value of current assets in 2024 was held by JSC "Poltavaholod" by 18.86%, followed by LLC "Lubensky Dairy Plant" by 14.95%, and the lowest growth of this indicator was recorded at LLC "Reshetylivskii Maslozavod" 0.11%. The analysis proved that "Reshetylivskii Maslozavod" LLC 0.11% is unable to maintain financial and economic security due to the weak level of efficiency of current assets. This company is the closest to bankruptcy among the other analyzed companies.

The specified method of analysis and forecasting of the company's current assets is of great importance for stimulating the financial and economic security of business entities. This technique will be useful for entrepreneurs who are developing promising strategies for the development of the enterprise, aimed at future development, taking into account the policy of resource conservation, environmentalization and effective use of human resources.

Keywords: *current assets, bankruptcy, financial and economic security, crisis, external environment, sustainable development, profitability, financial management, liquidity*

Introduction

Modeling the forecasting of current assets is a necessary condition for preventing the bankruptcy of business entities in conditions of crisis, growing uncertainty and turbulent changes in the external environment, which are currently present in the national economy of Ukraine. The intensification of the globalization of the economy, interstate movement of labor resources, increased competition in innovative entrepreneurship create a number of dangers for the effective functioning of industrial enterprises. Modern industrial enterprises, even without changes in the external environment, are in an extremely difficult situation. The lack of innovative activity in the production of industrial products, a weak investment strategy, the low quality of labor resources, as well as the obsolescence of fixed assets increase the risks for enterprises. In case of ineffective and untimely evaluation of current assets of industrial enterprises, in such unfavorable operating conditions, there are risks of bankruptcy. In this context, the problem of modeling the forecasting of current assets of industrial enterprises with the aim of preventing bankruptcy and increasing financial and economic security acquires strategic importance. Timely forecasting will allow market stakeholders to develop bankruptcy prevention strategies and hedge risks in conditions of uncertainty. The above also emphasizes the importance of adaptation of industrial enterprises to changes in response to economic and social challenges, which is possible only in the conditions of maintaining financial and economic security as a key element of managing these challenges. To achieve financial and economic security, it is important to develop and implement risk management strategies, increase competitiveness and promote innovation.

Modeling of forecasting current assets of industrial enterprises in order to prevent bankruptcy was studied by both domestic and foreign scientists. Many scientific works are devoted to the problems of increasing the financial and economic security of enterprises through effective management of current assets. n the article Severina and Vlasenko, [1], the main directions of modeling a complex system of supporting the economic security of entrepreneurship are defined and the structure of the financial and economic security management system is detailed. Particular importance is attached to the need to increase the value of current assets. Gudzenko and Shevchuk, [2], identified the features of internal control as a component of the accounting policy to avoid possible risks and threats to the enterprise's activity. Scientists also noted the need to deepen economic control in the security system of business entities during business operations and management of current assets. Pavlichenko, [3], noted the urgency of deepening the analysis of economic security and assets of Ukrainian enterprises in conditions of turbulence and financial and economic instability. The author noted the need for timely assessment of financial risks in conditions of instability in order to prevent bankruptcy. In the article Dmitrieva and Mordovtsev, [4], theoretical-methodical and practical proposals for improving methodological approaches in various areas of ensuring the financial security of the regions of Ukraine in the modern conditions of globalization of the economic sector were developed. The scientists proposed sectoral directions and measures to improve methodical approaches to ensure the financial security of the economy of the regions of Ukraine. Ivonchak, [5], offers methodical approaches to assessing the level of economic security and assets of business entities. The author details the tools for ensuring the economic security of entrepreneurship under the conditions of an unstable external environment. Quite interesting studies were conducted by Sun and Lei, [6]. Scientists based on neural networks carried out modeling of early financial warning of bankruptcy of listed mining companies. Using the example of China's mining companies in 2018, scientists suggested assessing the financial security of Chinese enterprises and determining the value of their current assets. Scientists have proposed targeted proposals for reducing the risks of industrial enterprises. Zhu *et al.*, [7], carried out a simulation of financial risk assessment "Z-Score" for intelligent enterprises. The authors proposed a system of early warning of bankruptcy and tools for increasing the solvency of companies. Zoričák *et al.*, [8], detailed the tools, financial parameters and methods of predicting bankruptcy for small and medium-sized enterprises. The authors prove that only timely prevention of bankruptcy will ensure the financial stability of the development of business entities. Many scientists (Qiao and Fei, [9], Hafezalkotob *et al.*, [10], Di Vaio *et al.*, [11], Zhao *et al.*, [12]), using innovative tools for diagnosing the financial and economic condition, offer non-standard techniques that can be used to prevent bankruptcy in today's conditions. Despite the fairly thorough research of scientists on the methods of diagnosing the financial or economic condition, estimating the value of current assets, preventing bankruptcy, identifying financial risks, etc., there is a need for a deeper analysis of the problems of modeling the forecasting of current assets of industrial enterprises in order to prevent bankruptcy. The purpose of the article is to forecast current assets of industrial enterprises in order to prevent bankruptcy and support financial and economic security.

Materials and Methods

Forecasting and modeling of current assets and bankruptcy of an enterprise is a rather complex process. The special Code of Ukraine on Bankruptcy Procedures regulates the procedure and conditions for recognizing business entities as bankrupt in order to satisfy creditors' claims [13]. According to the mentioned act, "The Code establishes the conditions and procedure for restoring the solvency of a debtor — a legal entity or declaring it bankrupt in order to

satisfy the demands of creditors, as well as restoring the solvency of an individual" [13]. That is, the procedure for the legislative regulation of bankruptcy is quite deep and well-founded. Indeed, preventing the bankruptcy of industrial enterprises in a turbulent environment is one of the main elements of supporting the financial and economic security of a business entity. Usually, the legislative regulation of the bankruptcy procedure is reduced to the procedure of pre-trial rehabilitation and financial restructuring. Precisely, this urgent problem of many business entities prompted research, modeling and forecasting of current assets of enterprises in order to prevent and avoid bankruptcy. Entrepreneurial activity and profitability are directly dependent on own working capital. Therefore, in this study, we will analyze and further forecast the cost of working capital of five milk processing enterprises of the Poltava region for five years: JSC "Poltavaholod", TM "Kozub Product", LLC "Reshetylivskiy Maslozavod", LLC "Lubensky Dairy Plant" (trademark "Harmony") and LLC "Orzhitskyi Molokozavod" (trademark "Zarog"). For a better understanding of the theoretical basis of the process of forecasting working capital, let's recall their definition in financial reporting. In particular, in the balance sheet (form No. 1 "Report on the financial condition of the enterprise"), working capital is defined as current assets and is reflected in the II asset section of the balance sheet. The dynamics of the value of current assets of five milk processing enterprises of the Poltava region over the past five years with reference to financial reporting form No. 1 Balance "Report on the financial condition of the enterprise" is presented in Table 1 [14–18].

Modeling and forecasting of current assets of industrial enterprises in order to prevent bankruptcy and support financial and economic security will be carried out using a system of statistical and economic-mathematical methods. At the same time, we will evaluate the value of current assets of five milk processing enterprises of the Poltava region over the past five years. At the beginning of the study, we will analyze the variation series of the value of current assets of five milk processing enterprises of the Poltava region in 2018–2022 using an economic and mathematical method. It is important to take into account that the value of current assets is influenced by receivables, production stocks, finished products, investments, liquidity of money. The specified indicators are constantly changing and are not constant, which is caused by the action of environmental factors. Therefore, it is important to study the value of variation of these indicators and their monitoring in dynamics. For this purpose, it is necessary to rank

Table 1

Dynamics of the value of current assets of five milk processing enterprises of the Poltava region, 2018–2022.

Enterprise	The value of current assets, thousand UAH				
	Years				
	2018	2019	2020	2021	2022
JSC "Poltavaholod"	49755	59914	62654	78498	94343
TM "Kozub Product"	19902	20560	21218	21876	22534
LLC "Reshetylivskiy Maslozavod"	58159	59130	59893	58002	52718
LLC "Lubensky Dairy Plant"	84640	86210	83918	114742	117726
LLC "Orzhitskyi Molokozavod"	24387	25824	23966	24108	22250

Source: [14–18]

Table 2

Ranking of the value of current assets of five milk processing enterprises of the Poltava region, 2018–2022.

Enterprise	2018	Ranking 2018	2019	Ranking 2019	2020	Ranking 2020	2021	Ranking 2021	2022	Ranking 2022	In average by ranking 2018–2022
	The value of current assets, thousand UAH. *Y*-levels of the indicator		The value of current assets, thousand UAH. *Y*-levels of the indicator		The value of current assets, thousand UAH. *Y*-levels of the indicator		The value of current assets, thousand UAH. *Y*-levels of the indicator		The value of current assets, thousand UAH. *Y*-levels of the indicator		
JSC "Poltavaholod"	49755	3	59914	2	62654	2	78498	2	94343	2	2
TM "Kozub Product"	19902	5	20560	5	21218	5	21876	5	22534	4	5
LLC "Reshetylivskiy Maslozavod"	58159	2	59130	3	59893	3	58002	3	52718	3	3
LLC "Lubensky Dairy Plant"	84640	1	86210	1	83918	1	114742	1	117726	1	1
LLC "Orzhitskyi Molokozavod"	24387	4	25824	4	23966	4	24108	4	22250	5	4

Source: calculated by the authors taking into account[14–18]

the milk processing enterprises of the Poltava region using the statistical function "rank" to perceive the economic status of the studied business entities and determine the top three (Table 2).

We observe stable leadership: LLC "Lubensky Dairy Plant" (trade mark "Harmony") — 1st ranking place, JSC "Poltavaholod" — 2nd ranking place and LLC "Reshetylivskiy Maslozavod" — 3rd.

Indicators of the value of current assets of these milk processing enterprises are growing annually, which indicates competitiveness, product quality, continuity of the production process, successful management decisions, and effectively selected personnel. As for the other two milk processing enterprises TM "Kozub Produkt" and LLC "Orzhitsky Molokozavod", the value of current assets both increases and fluctuates at the same time, which also indicates successful management of production and sale of products. Graphically, the ranking of the value of current assets of the five researched milk processing enterprises of the Poltava region over the past five years is presented in Fig. 1.

Next, we group by year indicators of the value of current assets of the five researched milk processing enterprises of the Poltava region, taking into account the rating assessment for their further analytical characteristics using variation series (Table 3).

As a result of data processing, a number of analytical characteristics of the value of current assets of the five researched milk processing enterprises of the Poltava region for the past five years were obtained, which are presented in the table. 4.

So, the analytical characterization of the value of current assets of five researched milk processing enterprises of the Poltava region over the past five years allows us to conclude that its value must be taken into account when minimizing or preventing bankruptcy of enterprises. Each subject of entrepreneurial activity has the opportunity to use the proposed methodology to support the financial and economic security of their activities, to plan risk management and anti-crisis measures.

3. Results and Discussion

Analytical characteristics of the value of current assets of JSC "Poltavaholod", TM "Kozub Product", LLC "Reshetylivskiy Maslozavod", LLC "Lubensky Dairy Plant", LLC "Orzhitskyi Molokozavod" made it possible to create a basis for further forecasting. Forecasting the value of current assets of the five researched milk processing enterprises of the Poltava region on 2024 is calculated using the built-in "trend" statistical function of "Microsoft Excel", which most accurately and qualitatively forecasts the studied indicators for the next period. Also, for forecasting the value of current assets of JSC "Poltavaholod", TM "Kozub Product", LLC "Reshetylivskiy Maslozavod", LLC "Lubensky Dairy Plant", LLC "Orzhitskyi

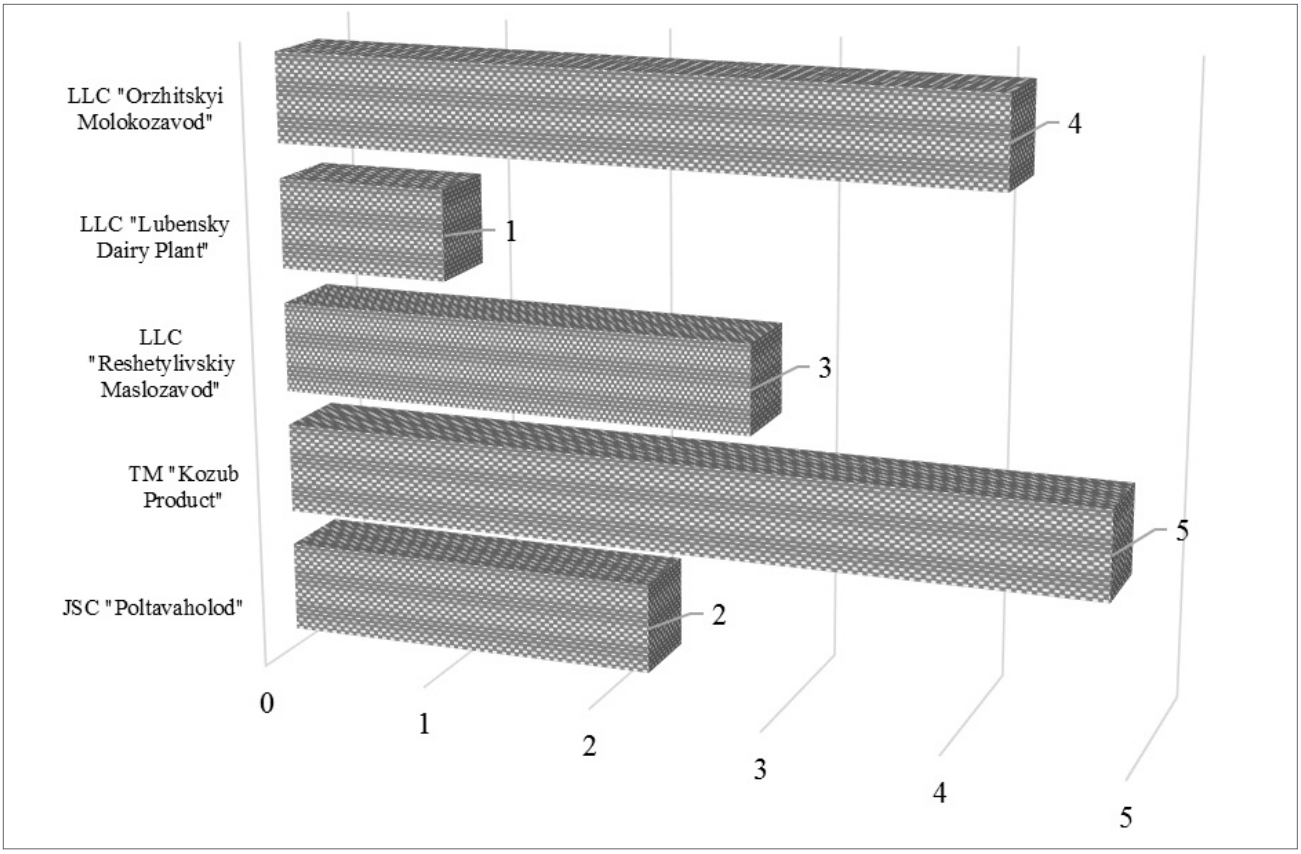

Figure 1. Ranking of the value of current assets five researched milk processing enterprises of the Poltava region, 2018–2022.

Source: suggested by the authors

Table 3

Grouping of indicators of the value of current assets of the five researched milk processing enterprises of the Poltava region, taking into account the rating assessment (calculation fragment of 2018 and 2022)

Analysis of variation series of the value of current assets, 2018.						
Enterprise	**Ranking 2018 (rank-function)**	**The value of current assets, thousand UAH. *Y*-levels of the indicator**	**$\|Y - Yc\|$**	**$(Y - Yc)^2$**	**$(Y - Yc)^3$**	**$(Y - Yc)^4$**
JSC "Poltavaholod"	3	49755	2386,40	5694904,96	13590321196,54	32431942503432,70
TM "Kozub Product"	5	19902	27466,60	754414115,56	-20721190746440,30	569140657756177000,00
LLC "Reshetylivskiy Maslozavod"	2	58159	10790,40	116432732,16	1256355753099,26	13556581118242300,00
LLC "Lubensky Dairy Plant"	1	84640	37271,40	1389157257,96	51775835824330,30	1929757887342950000,00
LLC "Orzhitskyi Molokozavod"	4	24387	22981,60	528153938,56	-12137822554410,50	278946582816440000,00
Analysis of variation series of the value of current assets, 2022						
Enterprise	**Ranking 2022 (rank-function)**	**The value of current assets, thousand UAH. *Y*-levels of the indicator**	**$\|Y - Yc\|$**	**$(Y - Yc)^2$**	**$(Y - Yc)^3$**	**$(Y - Yc)^4$**
JSC "Poltavaholod"	2	94343	32428,50	1051607726,03	34102062988629,50	1105878809454980000,00
TM "Kozub Product"	4	22534	39380,16	1550797388,52	-61070656905391,00	2404972540235630000,00
LLC "Reshetylivskiy Maslozavod"	3	52718	9196,01	84566545,07	-777674541883,02	7151500544521680,00
LLC "Lubensky Dairy Plant"	1	117726	55811,84	3114960935,86	173851686056835,00	9702981631926000000,00
LLC "Orzhitskyi Molokozavod"	5	22250	39664,16	1573245978,19	-62401487926456,20	2475102907886670000,00

Source: calculated by the authors taking into account [14–18]

Molokozavod", you can use the built-in "forecast", which is also linear and accurately creates the forecast of the indicator we need. When modeling the calculations of these functions, the results of the forecast of the value of current assets coincide. In this case, the manager of the enterprise or another interested person can choose any of the two considered methods of forecasting current assets. At the next stage, we determine the absolute and relative deviation of the forecast value of current assets in 2024 from the reported indicator of 2022 and analyze the changes (Table 5).

As a result of the calculation, the forecast values of the value of current assets of the five researched milk processing enterprises of the Poltava region for 2024 were obtained. As can be seen, the value of current assets increases to a greater and lesser extent, which may indicate sufficient resource potential, a rational policy of resource conservation and financial management. But, it should be emphasized that the analysis, modeling and forecasting of such processes is combined with the system of internal potential, the ability of the enterprise to adapt to an unstable and turbulent external environment. Therefore, each enterprise must develop its own strategy to minimize the negative impact of the external environment on the enterprise's activities and, at the same time, adhere to the policy of resource conservation. Taking into account the above, the correct identification of system elements, the identification of all transactional and transformational costs, and the establishment of the entire set of connections between them is important for the study of the financial and economic security of the enterprise. As a basis for improving the strategy of supporting the financial and economic security of the enterprise and preventing the situation of bankruptcy, it is necessary to

Table 4

Analytical characteristics of the value of current assets of the five researched milk processing enterprises of the Poltava region for 2018–2022

Indexes	2018	2019	2020	2021	2022
The average level of the series (thousand UAH)	47368,60	50327,60	50329,72	59445,18	61914,16
Limits of variation (thousand UAH)	19902/84640	20560/86210	21218/83918	21876/ 114742	22250/ 117726
Range of variation (thousand UAH)	64738	65650	62700	92866	95476
Coefficient of evenness (unit)	0,24	0,24	0,25	0,19	0,19
Average linear deviation (unit)	6726,43	7236,16	7396,72	9913,31	11765,38
Dispersion (unit)	186256863,28	196230957,55	194269665,51	405533177,96	491678571,58
Mean square deviation (unit)	13647,60	14008,25	13938,07	20137,85	22173,83
Coefficient of variation (unit)	28,81% /0,29	27,83% 0,28	27,69% 0,28	33,88% 0,34	35,81% 0,36
Asymmetry (unit)	0,53	0,16	-0,06	0,64	0,51
Excess (unit)	2,36	1,88	1,43	2,28	1,33
Median (unit)	49755,00	59130,00	59892,92	58001,75	52718,16
Intermediate level:					
for maximized indicators (unit)	2,80	2,92	3,00	2,59	2,63
for indicators that are minimized (unit)	11,90	12,24	11,86	13,59	13,91
The average level is the best option:					
for maximized indicators (unit)	16928,00	17242,00	16783,60	22948,40	23545,20
for indicators that are minimized (unit)	3980,40	4112,00	4243,60	4375,20	4450,00

Source: calculated by the authors

Table 5

Forecasting the value of current assets of the five researched milk processing enterprises of the Poltava region, 2024

Enterprise	The value of current assets, thousand UAH. *Y*-levels of the indicator					Forecast of the value of current assets, thousand UAH (2024)	Absolute deviation of the predicted value of the value of current assets in 2024 from the reported indicator of 2022, (+, –) thousand UAH	Relative deviation of the predicted value of the value of current assets in 2024 from the reported indicator of 2022, (%) thousand UAH
	2018	2019	2020	2021	2022			
JSC “Poltavaholod”	49755	59914	62654	78498	94343	112137	17794	18,86%
TM “Kozub Product”	19902	20560	21218	21876	22534	23850	1316	5,84%
LLC “Reshetylivskiy Maslozavod”	58159	59130	59893	58002	52718	52776	58	0,11%
LLC “Lubensky Dairy Plant”	84640	86210	83918	114742	117726	135329	17603	14,95%
LLC “Orzhitskyi Molokozavod”	24387	25824	23966	24108	22250	24154	1904	8,56%

Source: calculated by the authors

plan the policy of optimality of the value of current assets, which will serve as a map of the effective development of the subject of entrepreneurial activity and the prevention of bankruptcy. A balanced management of current assets and a financial strategy aimed at maintaining sustainable financial stability can help the enterprise avoid bankruptcy and achieve successful financial performance. Increasing the value of current assets can be achieved through inventory optimization, customer account and credit management, and effective cash flow management. To avoid bankruptcy, it is important to plan and manage current assets. This includes cost control, efficient use of resources and ensuring sustainable profitability.

Thus, financial analysis and forecasting of current assets are key aspects of the company’s

financial management aimed at ensuring its stability and efficiency. The policy of increasing the value of current assets and maintaining financial and economic security should include:

- effective inventory management: ensuring the optimal level of inventory allows you to avoid excessive use of funds and improve the turnover of assets;
- quick collection of payments and repayment of all current obligations: increasing the speed of receiving money for sold goods or services helps maintain cash flow and reduces the time of movement of funds in receivables;
- effective use of available and borrowed resources: maximization and effective use of external potential and other resources helps to increase the turnover of assets;
- effective financial planning: careful planning of financial needs and provision of adequate liquidity help to avoid problems with paying debts and other financial obligations;
- development of contingency plans: development of financial and economic strategies for solving operational problems and timely response to changes in the economic environment must be systematic and continuous;
- effective debt management: controlling the level of debt and servicing it is important to avoid bankruptcy.

In general, a successful combination of these directions will help business entities to increase their resilience to financial difficulties and ensure financial and economic security in the long term.

Graphical relative deviation of the predicted value the value of current assets in 2024 from the reporting indicator of 2022 of the five researched milk processing enterprises of the Poltava region is presented in fig. 2.

As can be seen from the figure, the largest projected increase in the value of current assets in 2024 was recorded in JSC "Poltavaholod" by 18.86%, followed by LLC "Lubensky Dairy Plant"by 14.95%, and the smallest increase in this indicator by LLC "Reshetilivskyi Maslozavod" 0, 11%. Therefore, the use of various methods of evaluating and forecasting economic indicators, in particular the value of current assets, allows them to be compared, ranked, modeled and forecasted, which is an important tool for policy formation to support the financial and economic security of enterprises. For an in-depth study of individual issues of the mentioned issues, as well as for further scientific developments regarding the improvement of the management system of financial and economic security of the enterprise and the development of a mechanism for its implementation in the practical activities of enterprises to prevent and avoid bankruptcy, there is a need to take into account the factors of the external environment in the process of modeling changes in current assets. Our further scientific research will be devoted to these questions.

Conclusions

Increasing the value of current assets and preventing bankruptcy are important aspects of managing the financial stability of the enterprise and supporting the financial and economic security of business entities, taking into account the turbulent external environment. That is why modeling the forecasting of current assets of enterprises is important for maintaining financial and economic security and preventing bankruptcy. The forecasting of the investigated

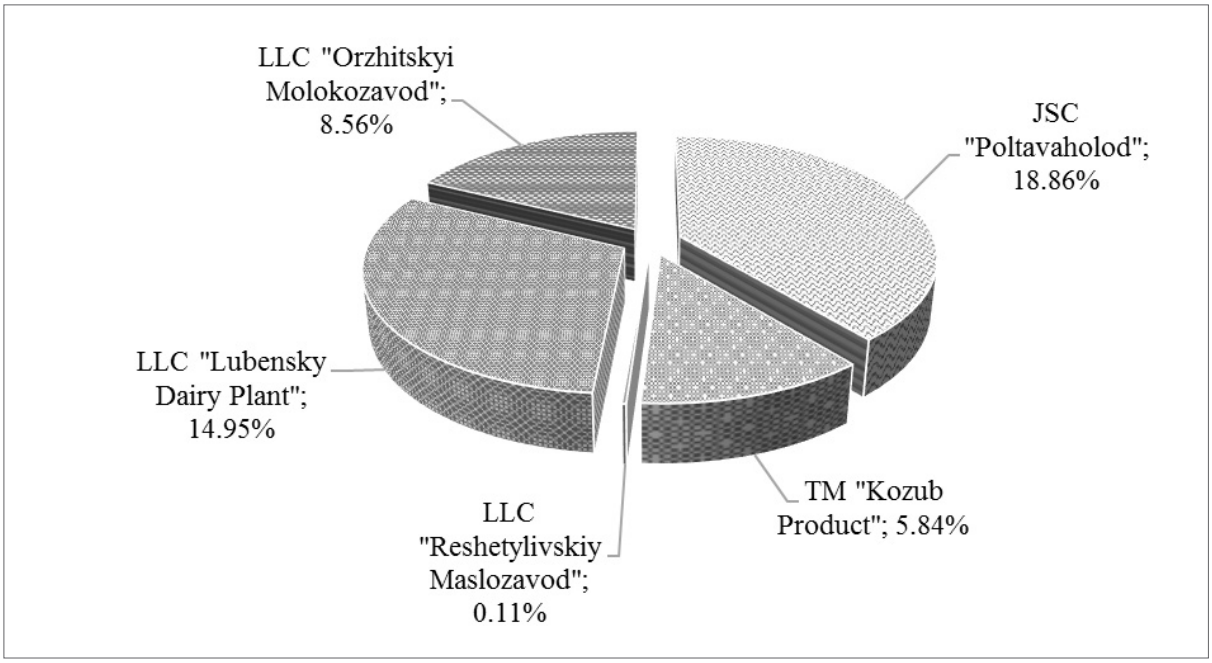

Figure 2. Predicted growth in the value of current assets of the five researched milk processing enterprises Poltava region, % 2024

Source: calculated by the authors

indicator showed that the largest projected increase in the value of current assets in JSC "Poltavaholod" is 18.86%, and the smallest increase in this indicator in 2024 is 0.11% in LLC "Reshetylivskiy Maslozavod". Obviously, the strategic growth policy of LLC "Reshetylivskiy Maslozavod" should be to increase the value of current assets, because without this, it is impossible to effectively maintain financial and economic security. Strategic growth policy measures include: implementation of tools aimed at optimizing the use of resources and improving the efficiency of operations; automation of inventory management systems; effective credit control and debt collection system; management of working capital, including cash reserves and short-term investments; implementation of modern technologies in production and personnel management; financial planning, budgeting and monitoring of investment policy. The use of these tools will help the enterprise to improve the use of current assets, to ensure profitability, liquidity and investment attractiveness in the conditions of the variability of the external environment.

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ПРОГНОЗУВАННЯ ОБОРОТНИХ АКТИВІВ ПІДПРИЄМСТВ ДЛЯ ПІДТРИМКИ ФІНАНСОВО-ЕКОНОМІЧНОЇ БЕЗПЕКИ ТА ПОПЕРЕДЖЕННЯ БАНКРУТСТВА

Анотація. *Оборотні активи є важливою частиною операційної діяльності будь-якого суб'єкту підприємницької діяльності і мають ключове значення у підтримці фінансово-економічної безпеки підприємства. Оборотні активи підприємства чинять вагомий вплив на виробничу діяльність, інновації, конкурентоспроможність, персонал, логістику тощо. Допомагають уникнути перерв у виробництві та ефективно комерціалізувати інноваційну продукцію на ринку. Неможливо сформувати ефективні фінансову та економічну політики та концепції інноваційного розвитку підприємства без урахування оборотних активів. Таким чином, постає концептуальна необхідність формування методології прогнозування оборотних активів підприємства, що забезпечить підтримку фінансово-економічної безпеки та попередить банкрутство.*

Інформаційним ресурсом для нашого дослідження слугували звітні данні АТ «Полтавахолод», ТМ «Козуб продукт», ТОВ «Решетилівський маслозавод», ТОВ «Лубенський молочний завод» (торгова марка «Гармонія») та ТОВ «Оржицький молокозавод» (торгова марка «Зарог») за період 2018–2022 рр. Для розуміння теоретичної сутності фінансової стійкості підприємства нами глибоко досліджувався інформаційний ресурс щодо законодавчого регулювання процедури банкрутства. З метою розкриття тематики статті нами використовувалася система статистичних та економіко-математичних методів.

Результати моделювання прогнозування оборотних активів підприємств засвідчили, що найбільше прогнозне зростання вартості оборотних активів у 2024 р. має АТ «Полтавахолод» 18,86%, далі ТОВ «Лубенський молочний завод» 14,95%, а найменше зростання цього показника зафіксовано на ТОВ «Решетилівський маслозавод» 0,11%. Аналіз засвідчив, що ТОВ «Решетилівський маслозавод» 0,11% через слабкий рівень ефективності оборотних активів неспроможне підтримувати фінансово-економічну безпеку. Зазначене підприємство найбільш серед інших аналізованих підприємств наближене до банкрутства.

Зазначена методика аналізу та прогнозування оборотних активів підприємства має велике значення для стимулювання фінансової та економічної безпеки суб'єктів підприємницької діяльності. Дана методика буде корисною для підприємців, які розробляють перспективні стратегії розвитку підприємства, що направлені на майбутній розвиток з урахуванням політики ресурсозбереження, екологізації та ефективного використання людського ресурсу.

Ключові слова: *оборотні активи, банкрутство, фінансово-економічна безпека, криза, зовнішнє середовище, сталий розвиток, прибутковість, фінансове управління, ліквідність.*

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INTEGRAL ASSESSMENT OF LEVEL OF SECURITY OF A COUNTRY'S POPULATION

Abstract. *Today's Ukrainian economy is facing super-heavy challenges, most of them caused by war, which require a rapid and adaptive response. Militarisation of the economy, financial expenditures and migration have caused numerous economic shocks and crises in the national economic system. From 2014 onwards, Ukraine has been fighting for its independence, but this fight is extremely difficult and resource-intensive. There is a need to support security not only militarily, but also economically, industrially, financially, etc. Human resources are the source that can support security in different sectors and industries. Therefore, assessing the level of human security is an important issue of our time that needs to be studied in more depth.*

The information source of our research is the data from the Internet resource http://data.un.org/, thanks to which we have attracted a significant array of statistical indicators to assess the level of safety of the population. The article uses the methods of mathematical modelling, analysis and statistical comparison. The system of statistical indicators reflecting its economic, demographic and social aspects was used for the integral assessment of the level of security of the country's population. On the basis of these indicators a single integral assessment has been developed. This assessment makes it possible to compare the state of security of the population in different countries and to identify a trend in the development of security in a particular country.

The proposed methodology was tested in 27 countries: Ukraine, Poland, Armenia, Azerbaijan, Bulgaria, Croatia, the Czech Republic, Estonia, Georgia, Hungary, Kazakhstan, Kyrgyzstan, Latvia, Lithuania, the Republic of Moldova, Austria, Belgium, Germany, Greece, Denmark, Ireland, Spain, Italy, Cyprus, Malta, France and Sweden. The results of the practical usage of the methodology to calculate the level of population security for the selected countries showed that Denmark, Ireland and Sweden had the highest security level for 2020, while Ukraine, Azerbaijan and Kazakhstan had the lowest.

The proposed methodology for the integral assessment of population security makes it possible to assess the level of security not only in a single country but also to compare this indicator with others. This will enable stakeholders to monitor population security, identify its problems and develop adaptive measures to improve it. This methodology is particularly relevant for countries with unstable institutional environments, ongoing military conflicts and unfavourable market conditions.

Keywords: *security, population, unemployment, refugees, life expectancy, balance of payments, healthcare, education.*

1. Introduction

The military operations in the East of Ukraine have shown how important it is to assess and take into account the security of the population, the economy, industry, production and the national economy as a whole in a timely manner. There is no state in the world for which monitoring the performance of any sector of the economy is not important. Each country is looking for new or improving existing methodologies, inventing adaptive mathematical tools for security assessment. In our case, the relevance of our study is enhanced by the fact that human resources are the main condition and driving force of scientific and technological progress and positive transformations in different sectors of the economy. That is why a timely diagnosis of population security is of great importance for the socio-economic development of the country. International comparison of the level of population security is also important in order to understand its state and identify areas for its improvement.

The aim of the article is to develop a methodology for the integral assessment of the level of security of a country's population and to adapt it to individual countries.

The assessment of the level of security has been disturbed in the scientific works of various scholars. Manrique-de-Lara-Pecate *et al.,* [1], have identified causal links between increases and decreases in -security level in the tourism sector. Quite interesting in the article is the study of the impact of terrorism on tourism security and the profitability of this sector of the economy. The authors rightly determine that uncertainty of the external environment, and imperfect infrastructure of tourism support require significant financial sources for tourist firm. Researchers used several scenarios of tourism profit fluctuations, depending on the level of security of the country.

Elavarasan *et al.,* [2], monitored the sustainable development of the energy system of 40 European countries. The proposed composite index is constructed using a methodology that can also be used in our study.

Qin *et al.,* [3], have analysed an important current issue — the importance of water, energy, food resources for ecology, sustainable development, security, poverty reduction and supporting human well-being in Central Asia.

Taifouris and Martнn, [4], investigated how interruptions in the supply of natural gas affected the energy security of European countries. The scientists have carried out a multi-scale analysis of the possibilities of implementing a circular economy that would reduce regional dependence on natural gas. Noteworthy is the rationale for the methodology that the authors used to address the problem.

Zhou *et al.,* [5], set out to explore a crucial question, how the Russia-Ukrainian war has affected global energy and food security. The article presents modelling scenarios of trade flows, risks and security pressures. The authors identify how international organisations can influence global energy and food demand between large and small countries.

Gasser, [6], analysed 63 indicators for quantifying the energy security of countries with regard to geographical coverage and time horizon. Using multivariate analysis, indicator normalisation, indicator weighting and aggregation, as well as an assessment of uncertainty, sensitivity and sustainability, the author investigated the challenges of security development in the energy sector. The results of the analysis revealed certain information support problems that should be considered in our study: an example is the lack of transparency in the choice of indicator set, normalisation, weighting and aggregation function.

In the scientific paper by He *et al.,* [7], the issue of reasonable usage of nitrogen in crop production to support environmental sustainability and food security is considered. The scientists evaluated the existing nitrogen fertilizer usage in maize, wheat and rice production for countries with different socio-economic development, which helped them develop alternative strategies to improve the environment in line with the UN 2050 Sustainable Development Goals. The analysis resulted in a forecast of nitrogen fertilizer usage and crop production to 2050 and approaches that could be applied to achieve the goals set by the authors of the article. The forecasting methods and models presented in the article can be used within the object of our study.

Grida *et al.,* [8], who analyses the cause of supply chain disruption through natural disasters or the COVID-19 epidemic, has carried out quite interesting studies. The impact of this epidemic has certainly caused changes in supply and demand for logistics flows. The indicators, functions, methods and tools used in the analysis are useful for modelling international comparisons of economic security.

A complex assessment of the level of financial security of Ukraine and the analysis of its individual factors are investigated in the work of Kotkovsky, [9]. The article analyses the changes in the integral indicators of the elements of financial security of Ukraine and identifies the discrepancy between the received data on financial security and its actual level. The authors proposed an innovative way to add an indicator of risks of financial behaviour of stakeholders related to savings and loan and foreign exchange transactions, as well as to improve the process of monitoring financial security with an increase of globalisation trends in financial markets.

Kizim's work is related to our research, where the level of economic security of Ukraine and the European Union countries has been assessed, [10]. The usage of correlation and cluster analysis, the method of taxonomy allowed the author to improve the methodology of economic security assessment. In the conclusion of the article, it is proved that it

is the economic sphere that is problematic for increasing the national economy of Ukraine.

Zachosova's work examines the specifics of analysing the level of financial security of the state and shows the importance of assessing the state of economic security of financial institutions in this process, [11]. It is significant for our study that the author has sufficiently thoroughly considered the specifics and shortcomings of the existing security assessment methodologies. Considering the aforementioned scientific studies and recognising their high utility for contemporary security assessment in different sectors of the economy, we will propose our own methodology of security assessment. As noted above, it is the availability of quality human resources and ensuring their security occupies an important place in the socio-economic development of the country.

2. Materials and Methods

A system of statistical indicators reflecting the country's economic, demographic and social aspects is used to integrally assess the level of security of the country's population. A single integral assessment is developed based on these indicators. Such an assessment makes it possible to compare the state of security of the population in different countries and to identify the trend of security development in a particular country. Let us denote by G the set of statistical indicators used in obtaining an integral assessment of the safety of the population. The set G is a union of $G = G_1 \cup G_2 \cup G_3$, where a subset G_1, includes economic indicators, G_2 includes demographic indicators, and G_3 includes social indicators. The indicators included in the subset G_i, let us denote by g_{ij}. Thus $G_i = \{g_{ij}\}_{j=1}^{n_i}$ and $G = \{\{g_{ij}\}_{j=1}^{n_i}\}_{i=1}^{3}$where n_i is = the number of indicators in the subset G_i.

A list of characteristics g_{ij} is shown in Table 1.

The values of the following indicators were used to determine the integral assessment of public safety for 2010, 2015 and 2020 in 27 countries: Ukraine, Poland, Armenia, Azerbaijan, Bulgaria, Croatia, Czech Republic, Estonia, Georgia, Hungary, Kazakhstan, Kyrgyzstan, Latvia, Lithuania, Rep. Moldova, Austria, Belgium, Germany, Greece, Denmark, Ireland, Spain, Italy, Cyprus, France, Malta, and Sweden. Let us put in a mutually unambiguous correspondence to each country an integer r from 1 to 27, and for each of the years under review an integer t, where to value $t = 1$ corresponds to the 2010 year, to value $t = 2\,2015$, and to $t = 3\,2020$. We denote the value of indicator g_{ij} in the r country in the t year by $g_{ij}(r, t)$. The values of $g_{1j}(r, t)$, reflecting the economic aspect of population security are shown in Table 2.

Based on the data, let us determine an integral estimate of the economic security component of the country's population. To do this, replace the indicators g_{1j} with the corresponding dimensionless indicators q_{1j}, whose values $q_{1j}(r, t)$ for all possible t and r refer to the interval [0; 1], and the growth of these indicators corresponds to the improvement of the state of population security. Since the indicators g_{1j} are stimulants, the value of $q_{1j}(r, t)$ can be determined by the equation:

$$q_{1j} = \frac{g_{1j}(r,t) - \min\limits_{r,t} g_{1j}(r,t)}{\max\limits_{r,t} g_{1j}(r,t) - \min\limits_{r,t} g_{1j}(r,t)}.$$

The integral estimate w_1 of the economic component of security is determined by a linear combination of indicators q_{1j} i.e.:

$$w_1(r,t) = \sum_{j=1}^{4} \alpha_j q_{1j}(r,t) c\,.$$

Table 1

Indicators for integral assessment of the security of a country's population

Indicator	Content of the indicator
Economic indicators (subset G_1)	
g_{11}	Annual GDP growth rate (%)
g_{12}	B GDP per capita (USD)
g_{13}	Balance of payments, current account (in millions of US dollars)
g_{14}	Expected increase in GDP per capita at a constant GDP growth rate (USD)
Demographic indicators (subset G_2)	
g_{21}	Annual population growth rate (%)
g_{22}	Fertility rate (live births per woman)
g_{23}	Life expectancy for women at birth (years)
g_{24}	Life expectancy for men at birth (years)
g_{25}	International migrant stock (percentage of the total population)
g_{26}	Refugees and others of concern to UNHCR (thousand people)
Social indicators (subset G_3)	
g_{31}	Unemployment rate (percentage of the labour force)
g_{32}	Healthcare expenditure (as a percentage of GDP)
g_{33}	Public spending on education (as a percentage of GDP)

Source: grouping of indicators proposed by the authors

Table 2

Significance of indicators of the economic component of population security for different countries

r	Country	g_{11}	g_{12}	g_{13}	g_{14}	g_{11}	g_{12}	g_{13}	g_{14}	g_{11}	g_{12}	g_{13}	g_{14}
		2010 year (t=1)				2015 year (t=2)				2020 year (t=3)			
1	Ukraine	0,3	2970,20	-3016	8,91	-9,8	2026,40	1616	-198,59	3,3	2956,90	-1322	97,58
2	Poland	3,6	12505,20	-25843	450,19	3,8	12556,70	-2626	477,15	5,1	15444,00	2776	787,64
3	Armenia	2,2	3432,10	-1261	75,51	3,2	3607,30	-287	115,43	5,2	4212,10	-1118	219,03
4	Azerbaijan	4,8	5857,30	15040	281,15	1,1	5515,70	-222	60,67	1,4	4717,7	4365	66,05
5	Bulgaria	0,6	6783,00	-965	40,70	4	7032,30	61	281,29	3,1	9387,80	2742	291,02
6	Croatia	-1,5	13818,30	-1485	-207,27	2,4	11701,40	1595	280,83	2,7	14674,00	1456	396,20
7	Czech	2,3	19691,30	-7351	452,90	5,3	17623,10	461	934,02	3	22992,10	-866	689,76
8	Estonia	2,7	14786,20	340	399,23	1,8	17523,30	403	315,42	4,8	23241,90	690	1115,61
9	Georgia	6,2	2986,8	-1199	185,18	3	3716,00	-1767	111,48	4,8	4396,70	-901	211,04
10	Hungary	0,7	13209,50	342	92,47	3,8	12735,80	2926	483,96	5,1	16264,00	-1247	829,46
11	Kazakhstan	7,3	9109,30	1386	664,98	1,2	10493,30	-6012	125,92	4,1	9789,50	-6498	401,37
12	Kyrgyzstan	-0,5	884,2	-475	-4,42	3,9	1120,70	-1052	43,71	3,5	1283,80	-962	44,93
13	Latvia	-4,5	11234,30	435	-505,54	3,3	13560,80	-241	447,51	4,6	17851,60	-176	821,17
14	Lithuania	1,5	11855,50	72	177,83	2	14118,00	-1015	282,36	3,6	19082,50	2298	686,97
15	Moldova	7,1	1707,00	-481	121,20	-0,3	1902,70	-463	-5,71	2,8	2791,00	-1159	78,15
16	Austria	1,8	46598,70	11472	838,78	1	43995,00	6634	439,95	2,4	51230,30	11714	1229,53
17	Belgium	2,9	43967,70	7338	1275,06	2	40941,90	6363	818,84	1,5	47293,00	-6512	709,40
18	Germany	4,2	42020,00	196172	1764,84	1,7	41088,80	288621	698,51	1,5	47513,70	274847	712,71
19	Greece	-5,5	27495,60	-30263	-1512,26	-0,4	18442,40	-1611	-73,77	1,9	20731,20	-2928	393,89
20	Denmark	1,9	57966,60	21051	1101,37	2,3	53206,10	24953	1223,74	2,4	61833,70	27581	1484,01
21	Ireland	1,8	48777,60	2320	878,00	25,2	62655,50	31682	15789,19	8,2	79414,60	-36374	6512,00
22	Spain	0,2	30272,60	-52250	60,55	3,8	25606,80	24108	973,06	2,4	30405,80	27724	729,74
23	Italy	1,7	35971,50	-70819	611,52	0,8	30306,10	25379	242,45	0,8	34388,50	58933	275,11
24	Cyprus	2	30993,10	-2799	619,86	3,4	23323,40	-84	793,00	4,1	28967,60	-1655	1187,67
25	Malta	3,5	21099,50	-420	738,48	10,7	24685,00	301	2641,30	6,6	33122,80	1436	2186,10
26	France	1,9	40685,30	-22031	773,02	1,1	36611,80	-9130	402,73	1,7	41358,10	-18549	703,09
27	Sweden	6,2	52749,70	29196	3270,48	4,4	51577,4	20695	2269,41	2,2	55766,80	20783	1226,87

Source: http://data.un.org/

The weighting coefficients α_j are determined by the modified principal component method. To do this, we determine the covariance coefficients $\rho_1(j_1, j_2) = cov\left(q_{1j_1}, q_{1j_2}\right)$ between indices q_{1j}. The covariance matrix K_1, the elements of which are these coefficients, looks like:

$$K_1 = \begin{pmatrix} 0,01125 & 0,00545 & 0,00048 & 0,00930 \\ 0,00545 & 0,05527 & 0,00844 & 0,01350 \\ 0,00048 & 0,00844 & 0,02019 & 0,00128 \\ 0,00930 & 0,01350 & 0,00128 & 0,01228 \end{pmatrix}$$

The maximum eigenvalue of $\lambda_1^{\max}$ of matrix K_1 is 0.0489, and its corresponding eigenvector $A_1 = (a_{11}, a_{12}, a_{13}, a_{14})$ has coordinates $a_{11} = 0,1837$, $a_{12} = 0,8926$, $a_{13} = 0,1623$, $a_{14} = 0,3783$. The weights coefficients α_j in the integral estimation W_1, are considered proportional to the squares of the coordinates of the given vector:

$$\alpha_j = \frac{a_{1j}^2}{\sum_{j=1}^{4} a_{1j}^2}.$$

The coefficients found by this method are $\alpha_1 = 0,03375$, $\alpha_2 = 0,79673$, $\alpha_3 = 0,02634$, $\alpha_4 = 0,14311$. Thus, the integral estimation of the economic component of the population's security is determined by the formula:

$$w_1(r, t) = 0,03375q_{11}(r, t) + 0,79673q_{12}(r, t) + 0,02634q_{13}(r, t) + 0,14311q_{14}(r, t).$$

The values of $g_{2j}(r, t)$, reflecting the demographic component of security are shown in Table 3.

Determine an integral estimate of the demographic component of the safety of a country's population. Based on the indicators g_{2j} we define dimensionless indicators q_{2j} whose values for all countries and years under consideration fall within the interval [0;1], with an increase in these indicators corresponding to an improvement in the state of security. Since the indicators g_{21}, g_{22}, g_{23} and g_{24} are stimulants, we define their corresponding values $q_{2j}(r, t)$ by the equation:

$$q_{2j} = \frac{g_{2j}(r,t) - \min\limits_{r,t} g_{2j}(r,t)}{\max\limits_{r,t} g_{2j}(r,t) - \min\limits_{r,t} g_{2j}(r,t)}.$$

The indicators g_{25}, and g_{26} are destimulants, hence their corresponding values $q_{2j}(r, t)$ are determined by the equation:

Table 3

Values of indicators of the demographic component of population security across countries

r	Country	g_{21}	g_{22}	g_{23}	g_{24}	g_{25}	g_{26}
2010 year (t = 1)							
1	Ukraine	-0,5	1,4	73,8	62,2	10,5	46,4
2	Poland	0	1,4	79,8	71,3	1,7	18,4
3	Armenia	-0,7	1,7	75,8	69,4	7,3	85,8
4	Azerbaijan	1,1	1,8	73,4	66,9	3,1	596,9
5	Bulgaria	-0,7	1,5	76,8	69,7	1	6,9
6	Croatia	-0,2	1,5	79,5	72,6	13,2	25,5
7	Czech Republic	0,5	1,4	80,1	73,8	3,80	3,5
8	Estonia	-0,4	1,7	79	68,3	16,4	101
9	Georgia	-0,5	1,8	75,3	66,2	1,8	362,2
10	Hungary	-0,3	1,3	77,8	69,6	4,4	5,8
11	Kazakhstan	1,1	2,5	71,9	60,6	20,5	12,7
12	Kyrgyzstan	1,3	2,8	71,7	63,5	4,3	304,2
13	Latvia	-1,2	1,5	77	66	14,8	327
14	Lithuania	-1,4	1,4	77,8	66	5,1	4,6
15	Republic of Moldova	-0,4	1,3	72,1	64,4	3,2	2,3
16	Austria	0,4	1,4	82,8	77,3	15,2	68,7
17	Belgium	0,7	1,8	82,3	76,8	13,7	36,9
18	Germany	-0,2	1,4	82,4	77	12,1	670,6
19	Greece	-0,6	1,4	82,8	77,3	12,1	57,4
20	Denmark	0,5	1,9	80,8	76,4	9	24,5
21	Ireland	1,9	2	82	77,4	16	14,2
22	Spain	1,3	1,5	84,4	78,1	13,4	6,6
23	Italy	0,4	1,4	84,1	78,8	9,8	61,3
24	Cyprus	1,6	1,5	81,1	76,8	17,2	8,8
25	Malta	0,5	1,4	82,4	78,1	8	7,4
26	France	0,6	2	84,3	77,5	11,6	250,4
27	Sweden	0,8	1,9	83,1	79	14,7	110,8
2015 year (t = 2)							
1	Ukraine	-0,4	1,5	75,8	65,8	10,9	1426,6
2	Poland	-0,2	1,3	81,2	73,1	1,6	29
3	Armenia	0,3	1,7	77	70,6	6,5	16
4	Azerbaijan	1,3	2,1	74,6	68,6	2,7	628,1
5	Bulgaria	-0,6	1,5	77,8	70,8	1,7	19
6	Croatia	-0,4	1,5	80,6	74,2	13,3	17,5
7	Czech Republic	0,1	1,5	81,2	75,1	3,9	5
8	Estonia	-0,3	1,6	81,2	71,8	14,8	86,8
9	Georgia	-0,4	2	76,8	67,8	1,9	268,3
10	Hungary	-0,3	1,3	78,7	71,6	4,9	28,8
11	Kazakhstan	1,6	2,7	73,9	64,3	20,2	7,8
12	Kyrgyzstan	1,9	3,3	74,3	66,4	3,4	14,3
13	Latvia	-1,2	1,5	78,8	69	13,3	263,2
14	Lithuania	-1,3	1,6	79,3	68,5	4,6	4,7
15	Republic of Moldova	-0,1	1,3	75,2	66,7	2,6	6,8
16	Austria	0,6	1,4	83,5	78,4	17,2	92,2
17	Belgium	0,6	1,8	83	78	15,8	45,8
18	Germany	0,2	1,4	82,9	77,9	12,5	573,8
19	Greece	-0,4	1,3	83,7	78,5	11,7	37,6
20	Denmark	0,5	1,7	82,2	78,1	10,5	27,3
21	Ireland	0,4	2	82,5	78,7	16,3	10,5
22	Spain	-0,1	1,3	85,3	79,6	12,6	17,3

Continuation of table 3

23	Italy	0,4	1,4	84,7	79,9	9,6	142,6
24	Cyprus	0,9	1,4	82,2	77,7	16,5	14,1
25	Malta	0,9	1,4	83,4	79,4	12,1	6,5
26	France	0,5	2	85	78,7	12,2	320,1
27	Sweden	0,8	1,9	83,8	80	17,2	225,5
2020 year (t = 3)							
1	Ukraine	-0,5	1,4	76,6	66,8	11,3	1540,4
2	Poland	-0,1	1,4	82,4	74,5	1,7	26,5
3	Armenia	0,3	1,8	78,3	71,1	6,4	19
4	Azerbaijan	1	2,1	75,3	70,3	2,5	625,2
5	Bulgaria	-0,7	1,6	78,5	71,3	2,4	21,2
6	Croatia	-0,6	1,4	81,4	75	12,5	8,3
7	Czech Republic	0,2	1,6	81,8	76,5	4,8	5,7
8	Estonia	0,2	1,6	82,5	74	14,4	77
9	Georgia	-0,2	2,1	77,9	69,1	2	287,4
10	Hungary	-0,2	1,5	80,1	73	5,3	6,4
11	Kazakhstan	1,3	2,8	77,4	68,8	20	8,9
12	Kyrgyzstan	1,8	3	75,4	67,2	3,1	0,6
13	Latvia	-1,1	1,7	79,8	69,9	12,4	225,5
14	Lithuania	-1,5	1,7	81,1	70	4,2	5,1
15	Republic of Moldova	-0,2	1,3	75,9	67,4	2,6	4,2
16	Austria	0,7	1,5	83,8	78,9	19,9	163,7
17	Belgium	0,5	1,7	83,7	79	17,2	83,5
18	Germany	0,5	1,6	83,6	78,7	15,7	1461
19	Greece	-0,4	1,3	84,5	79,5	11,6	147,1
20	Denmark	0,4	1,8	82,7	78,7	12,5	47,4
21	Ireland	1,2	1,8	83,7	80,4	17,1	14,4
22	Spain	0	1,3	86	80,6	13,1	149,1
23	Italy	0	1,3	85,4	81	10,4	261,4
24	Cyprus	0,8	1,3	82,8	78,6	16	33,3
25	Malta	0,4	1,4	84,1	80,4	19,3	10,7
26	France	0,3	1,9	85,4	79,4	12,8	473,4
27	Sweden	0,7	1,8	84,4	80,8	20	310,4

Source: http://data.un.org/

$$q_{2j} = \frac{\max\limits_{r,t} g_{2j}(r,t) - g_{2j}(r,t)}{\max\limits_{r,t} g_{2j}(r,t) - \min\limits_{r,t} g_{2j}(r,t)}.$$

The integral estimate w_2 of the demographic component of the security is determined by a linear combination of indicators q_{2j}:

$$w_2(r,t) = \sum_{j=1}^{6} \beta_j q_{2j}(r,t).$$

We determine the weighting coefficients β_j, using the modified principal component method. We determine the covariance coefficients. $\rho_2(j_1, j_2) = \operatorname{cov}\left(q_{2j_1}, q_{2j_2}\right)$ between indicators q_{2j}. The covariance matrix K_2 compiled from these coefficients looks like:

$$K_2 = \begin{pmatrix} 0,05179 & 0,02616 & 0,00276 & 0,01390 & -0,02087 & 0,00199 \\ 0,02616 & 0,04170 & -0,02145 & -0,01844 & -0,00216 & 0,00004 \\ 0,00276 & -0,02145 & 0,06684 & 0,06488 & -0,03546 & 0,00532 \\ 0,01390 & -0,01844 & 0,06488 & 0,07003 & -0,03494 & 0,00543 \\ -0,02087 & -0,00216 & -0,03546 & -0,03494 & 0,08833 & 0,00220 \\ 0,00199 & 0,00004 & 0,00532 & 0,00543 & 0,00220 & 0,03947 \end{pmatrix}$$

The maximum eigenvalue of λ_2^{max} of matrix K_2 is 0.1720, and its corresponding eigenvector $A_2 = (a_{21}, a_{22}, a_{23}, a_{24}, a_{25}, a_{26})$ has coordinates $a_{21} = 0,1422$, $a_{22} = -0,1417$, $a_{23} = 0,5769$, $a_{24} = 0,5932$, $a_{25} = -0,5228$, $a_{26} = 0,0409$. The weighting coefficients α_j, in the integral estimator W_2, are assumed to be proportional to the squares of the coordinates of a given vector:

$$\beta_j = \frac{a_{2j}^2}{\sum_{j=1}^{6} a_{2j}^2}.$$

The coefficients found by this method are $\beta_1 = 0,02022$, $\beta_2 = 0,02008$, $\beta_3 = 0,33281$, $\beta_4 = 0,35189$, $\beta_5 = 0,27332$, $\beta_6 = 0,14311$. Thus, the integral estimate of the economic component of population security is determined by the formula:

$$w_2(r, t) = 0,02022q_{21}(r, t) + 0,02008q_{22}(r, t) + 0,33281q_{23}(r, t) + 0,35189q_{24}(r, t) + 0,27332q_{25}(r, t) + 0,14311q_{26}(r, t).$$

The values of $g_{3j}(r, t)$, which reflect the indicators of the social component of safety, are shown in table 4.

To determine the integral assessment of the social component, we define the corresponding indicators g_{3j} dimensionless indicators g_{3j} the values of which refer to the interval [0;1], whereby an increase in these indicators means an improvement in the state of security of the population. Since the indicators g_{32} and g_{33} are stimulants, their corresponding values $q_{31}(r, t)$ and $q_{32}(r, t)$ are determined based on the equality:

$$q_{3j} = \frac{g_{3j}(r,t) - \min\limits_{r,t} g_{3j}(r,t)}{\max\limits_{r,t} g_{3j}(r,t) - \min\limits_{r,t} g_{3j}(r,t)}.$$

The indicator g_{31} is a destimulant, therefore the value of $q_{31}(r, t)$ is determined on the basis of equality:

$$q_{31} = \frac{\max\limits_{r,t} g_{31}(r,t) - g_{31}(r,t)}{\max\limits_{r,t} g_{31}(r,t) - \min\limits_{r,t} g_{31}(r,t)}.$$

The integral estimate w_3 of the social component is determined by a linear combination of indicators q_{3j}:

$$w_3(r,t) = \sum_{j=1}^{3} \gamma_j q_{3j}(r,t).$$

The weighting coefficients γ_j are determined by the modified principal component method. We calculate the covariance coefficients between indices q_{3j}. The covariance matrix K_3, composed of these coefficients, has the following form:

$$K_3 = \begin{pmatrix} 0,04459 & -0,00307 & 0,01090 \\ -0,00307 & 0,04983 & 0,01624 \\ 0,01090 & 0,01624 & 0,04201 \end{pmatrix}.$$

The maximum eigenvalue of λ_3^{max} value of matrix K_3 is 0.0638, and its corresponding eigenvector $A_3 = (a_{31}, a_{32}, a_{33})$ has coordinates $a_{31} = -0,2599$, $a_{32} = -0,7073$, $a_{33} = -0,6574$. Weighting coefficients γ_j in the integral estimation of W_3 are assumed to be proportional to the squares of the coordinates of the given vector, i.e.:

Table 4

Values of indicators of the social component of population security for different countries

r	Country	g_{31}	g_{32}	g_{33}	g_{31}	g_{32}	g_{33}	g_{31}	g_{32}	g_{33}
		2010 year (t=1)			2015 year (t=2)			2020 year (t=3)		
1	Ukraine	0,80	6,80	7,3	9,10	6,90	5,9	8,9	7,00	5
2	Poland	9,60	6,4	5,1	7,5	6,4	4,8	3	6,50	5
3	Armenia	19	9,2	3,2	18,3	10,1	2,8	1,6	10,40	3
4	Azerbaijan	5,6	4,8	2,8	5	6,7	3	6	6,7	3
5	Bulgaria	10,3	7,1	3,9	9,1	8,2	4,1	3,8	8,10	4,2
6	Croatia	11,6	8,1	4,2	16,2	6,8	4,6	7,1	6,80	4,6
7	Czech Republic	7,3	6,9	4,1	5	7,2	5,8	1,9	7,20	5,6
8	Estonia	16,7	6,3	5,5	6,2	6,4	5,1	5,4	6,40	5,2
9	Georgia	20,2	9,5	3,2	16,5	7,9	2	14,7	7,60	3,8
10	Hungary	11,2	7,5	4,8	6,8	7	4,6	3,5	6,90	5
11	Kazakhstan	5,8	2,7	3,1	4,9	3	2,8	4,6	3,10	2,8
12	Kyrgyzstan	8,6	7	5,8	7,6	7,1	6	6,6	6,20	6,1
13	Latvia	19,5	6,1	5,1	9,9	5,7	5,3	6,5	6,00	4,7
14	Lithuania	17,8	6,8	5,3	9,1	6,5	4,2	6,3	6,50	4
15	Republic of Moldova	7,4	10,1	9,1	3,7	8,6	7,5	5,4	7,00	7
16	Austria	4,8	10,2	5,7	5,7	10,4	5,5	4,8	10,40	5,5
17	Belgium	8,3	10	6,4	8,5	10,3	6,5	5,7	10,30	6,5
18	Germany	7	11	4,9	4,6	11,1	4,8	3	11,20	4,8
19	Greece	12,7	9,6	4	24,9	8,1	4	15,5	8,00	4
20	Denmark	7,5	10,3	8,6	6,2	10,2	7,6	4,8	10,10	8
21	Ireland	14,5	10,5	6	9,9	7,3	3,8	5,2	7,20	3,7
22	Spain	19,9	9	4,8	22,1	9,1	4,3	13	8,90	4,2
23	Italy	8,4	9	4,4	11,9	9	4,1	9,8	8,80	3,8
24	Cyprus	6,3	6,3	6,6	14,9	6,8	6,4	7,2	6,70	6,4
25	Malta	6,8	8,2	6,5	5,4	9,2	5,3	3,4	9,30	5,4
26	France	8,9	11,2	5,7	10,4	11,5	5,5	8,3	11,30	5,4
27	Sweden	8,6	8,5	6,6	7,4	11	7,5	6,7	11,00	7,7

Source: http://data.un.org/

$$\gamma_j = \frac{a_{3j}^2}{\sum_{j=1}^{3} a_{3j}^2}.$$

The coefficients determined from this equality are $\gamma_1 = 0{,}06755$, $\gamma_2 = 0{,}50027$, $\gamma_3 = 0{,}43217$. Thus, the integral assessment of the social component of the security of the country's population is determined by the formula:

$w_3(r, t) = 0{,}06755q_{31}(r, t) + 0{,}50027q_{32}(r, t) + 0{,}43217q_{33}(r, t)$.

Based on the derived integral assessments of the safety components of the population, we define an integral assessment of the safety of the population as a whole. This assessment is a linear combination of the integral assessments w_1, w_2 and w_3 i.e. looks like:

$$w(r,t) = \sum_{i=1}^{3} \eta_i w_i$$

The weighting factors η_i of the estimates w_i are proportional to the squares of the coordinates of the eigenvector A, which corresponds to the maximum eigenvalue λ^{max} of the covariance matrix K of these estimates. This covariance matrix has the form:

$$K = \begin{pmatrix} 0{,}03919 & 0{,}01808 & 0{,}01782 \\ 0{,}01808 & 0{,}02797 & 0{,}01172 \\ 0{,}01782 & 0{,}01172 & 0{,}02421 \end{pmatrix}$$

its maximum eigenvalue $\lambda^{max} = 0{,}0639$, and the corresponding eigenvector A = (0,7159; 0,5139; 0,4727). The weighting coefficients of the population security components are $\eta_1 = 0{,}51251$, $\eta_2 = 0{,}26409$, $\eta_3 = 0{,}22345$. Thus, an integral assessment of the security of the country's population is determined by the equality:

$w(r, t) = 0{,}51251w_1(r, t) + 0{,}26409w_2(r, t) + 0{,}22345w_3(r, t)$.

3. Results and Discussion

Certain integral assessments of the safety of the population and its constituents are shown in Table 5.

Integral security assessments of different countries for 2020 are shown in Figure 1.

Among the countries studied, three countries have integral scores above 0.65 for 2020 — Denmark, Ireland and Sweden. Germany, Austria, Belgium and France have scores between 0.55 and 0.65. Malta and Italy have scores slightly above 0.5. The remaining countries have scores below 0.5.

Figure 2 shows the dynamics of the integral assessment of population security and its components in Ukraine.

The lowest of the estimates of the population security components for Ukraine is the estimate of the economic component. It decreased by 42.7% in 2015 compared to 2010 and increased by 87.5% in 2020 compared to 2015 and exceeded the 2010 level by 0.00362. As the economic component has the highest weighting factor in the overall integral security assessment, its low level in Ukraine has a significant impact on the overall integral assessment. Ukraine has the highest estimate of the demographic component,

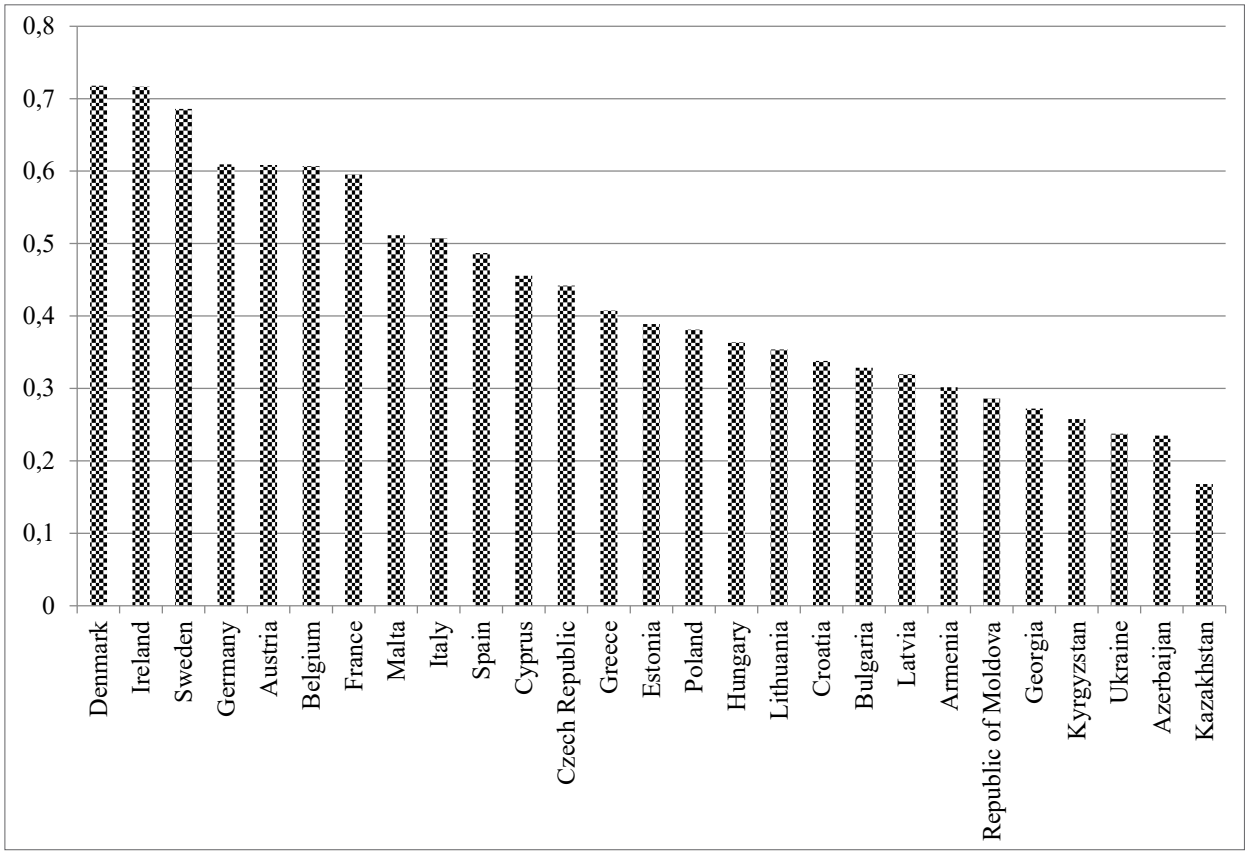

Figure 1. Integral estimates of the safety of countries' populations in 2020

Source: calculated by the authors

Table 5

Integral assessments of the safety of the population and its constituents

r	Country	Components of public safety			General integral assessment of public safety
		Economic	Demographic	Social	
2010 year (t = 1)					
1	Ukraine	0,04845	0,62324	0,22521	0,23975
2	Poland	0,15035	0,44192	0,64817	0,33860
3	Armenia	0,05565	0,45910	0,44259	0,24866
4	Azerbaijan	0,08566	0,22217	0,41363	0,19500
5	Bulgaria	0,08784	0,40671	0,55742	0,27698
6	Croatia	0,15510	0,47818	0,50223	0,31800
7	Czech Republic	0,22338	0,41592	0,67183	0,37445
8	Estonia	0,17412	0,44068	0,37231	0,28881
9	Georgia	0,05590	0,47279	0,45474	0,25512
10	Hungary	0,15366	0,48171	0,53168	0,32477
11	Kazakhstan	0,12324	0,12049	0,03382	0,10254
12	Kyrgyzstan	0,02659	0,52144	0,31014	0,22064
13	Latvia	0,12367	0,39712	0,30150	0,23563
14	Lithuania	0,14138	0,45385	0,45424	0,29382
15	Republic of Moldova	0,04331	0,90191	0,32555	0,33313
16	Austria	0,50046	0,70792	0,63459	0,58525
17	Belgium	0,47813	0,72935	0,64119	0,58094
18	Germany	0,47752	0,69854	0,65934	0,57654
19	Greece	0,27711	0,54819	0,67211	0,43697
20	Denmark	0,61877	0,88256	0,66508	0,69881
21	Ireland	0,52222	0,71605	0,62149	0,59562
22	Spain	0,32217	0,54260	0,71728	0,46869
23	Italy	0,38464	0,55048	0,76642	0,51376
24	Cyprus	0,33947	0,53679	0,56657	0,44234
25	Malta	0,24170	0,63732	0,74066	0,45768
26	France	0,43756	0,75328	0,73043	0,58640
27	Sweden	0,58852	0,65541	0,68526	0,62783
2015 year (t = 2)					
1	Ukraine	0,02776	0,52044	0,32835	0,22504
2	Poland	0,15299	0,42955	0,71100	0,35072
3	Armenia	0,05879	0,48788	0,50845	0,27259
4	Azerbaijan	0,07568	0,34404	0,48066	0,23705
5	Bulgaria	0,09571	0,48478	0,59043	0,30901
6	Croatia	0,14165	0,41573	0,55285	0,30592
7	Czech Republic	0,20984	0,54290	0,71708	0,41115
8	Estonia	0,20033	0,45145	0,50591	0,33494
9	Georgia	0,05956	0,31916	0,51855	0,23068
10	Hungary	0,15527	0,45344	0,58009	0,32895
11	Kazakhstan	0,12640	0,12181	0,15339	0,13122
12	Kyrgyzstan	0,03359	0,54210	0,44220	0,25919
13	Latvia	0,16262	0,41346	0,41624	0,28554
14	Lithuania	0,16560	0,39422	0,54188	0,31007
15	Republic of Moldova	0,03711	0,72961	0,44756	0,31171
16	Austria	0,46962	0,70460	0,64299	0,57044
17	Belgium	0,44272	0,75193	0,64814	0,57031
18	Germany	0,46361	0,70487	0,68337	0,57646
19	Greece	0,20417	0,42873	0,71957	0,37865
20	Denmark	0,57215	0,81965	0,70396	0,66699
21	Ireland	0,81107	0,41311	0,64243	0,66833

Continuation of table 5

22	Spain	0,29145	0,51168	0,76497	**0,45543**
23	Italy	0,33029	0,52241	0,80207	**0,48646**
24	Cyprus	0,26464	0,52894	0,61234	**0,41214**
25	Malta	0,30081	0,62505	0,73127	**0,48264**
26	France	0,39335	0,75396	0,75834	**0,57016**
27	Sweden	0,56599	0,85568	0,68363	**0,66881**
2020 year (t=3)					
1	Ukraine	0,05207	0,49625	0,35689	**0,23749**
2	Poland	0,18650	0,43567	0,76328	**0,38119**
3	Armenia	0,06765	0,54565	0,54973	**0,30161**
4	Azerbaijan	0,06826	0,31081	0,52729	**0,23489**
5	Bulgaria	0,11902	0,50004	0,60595	**0,32845**
6	Croatia	0,17304	0,44123	0,59430	**0,33800**
7	Czech Republic	0,25998	0,53942	0,74418	**0,44198**
8	Estonia	0,26789	0,45978	0,58271	**0,38892**
9	Georgia	0,06909	0,41672	0,56734	**0,27223**
10	Hungary	0,19487	0,46310	0,63385	**0,36380**
11	Kazakhstan	0,12429	0,12833	0,31449	**0,16786**
12	Kyrgyzstan	0,03488	0,49983	0,48221	**0,25762**
13	Latvia	0,21051	0,40352	0,47029	**0,31954**
14	Lithuania	0,22110	0,38990	0,61507	**0,35372**
15	Republic of Moldova	0,04975	0,58519	0,47534	**0,28626**
16	Austria	0,55128	0,70712	0,62227	**0,60833**
17	Belgium	0,50483	0,75978	0,66042	**0,60695**
18	Germany	0,52771	0,71504	0,67144	**0,60933**
19	Greece	0,23338	0,44939	0,75672	**0,40738**
20	Denmark	0,66212	0,84224	0,69830	**0,71781**
21	Ireland	0,88299	0,41452	0,69121	**0,71646**
22	Spain	0,33704	0,51973	0,79195	**0,48695**
23	Italy	0,37443	0,49867	0,82261	**0,50741**
24	Cyprus	0,32573	0,54483	0,64722	**0,45544**
25	Malta	0,37878	0,64242	0,66092	**0,51147**
26	France	0,44387	0,74239	0,76895	**0,59537**
27	Sweden	0,59775	0,86982	0,67046	**0,68588**

Source: calculated by the authors

but there is a clear downward trend in its dynamics. At the same time, the assessment of the social component increases significantly. The overall assessment of population security in Ukraine was 0.23975 in 2010, 0.22504 in 2015 and 0.23749 in 2020, which means that it remained almost unchanged.

4. Conclusions

Thus, we have proposed a methodology for integral assessment of the level of security of the country's population. The proposed methodology is based on assessing the level of security of the country's population using a system of statistical indicators that reflect its economic, demographic and social aspects. This assessment makes it possible to compare the state of security of the population in different countries and to identify the trend of security development in a particular country. It is determined that among the countries, studied three countries have integral scores exceeding 0.65 for 2020 — these are Denmark, Ireland and Sweden. Germany, Austria, Belgium and France have scores between 0.55 and 0.65. Malta and Italy have scores slightly above 0.5. The remaining countries have scores below 0.5 (out of a maximum possible score of 1). Denmark, Ireland and Sweden have high levels of population security, which guarantees their positive social development and shows how much these countries care about the available human resources. Public policy measures in these countries should be studied and examined in detail. The most positive measures should be adapted in each country in the world to increase the level of human security. For Ukraine, it is especially important to increase the economic component of population security, because it is the lowest among all the components assessed. In our future studies, directions for increasing the population's security will be proposed taking into account our proposed modelling.

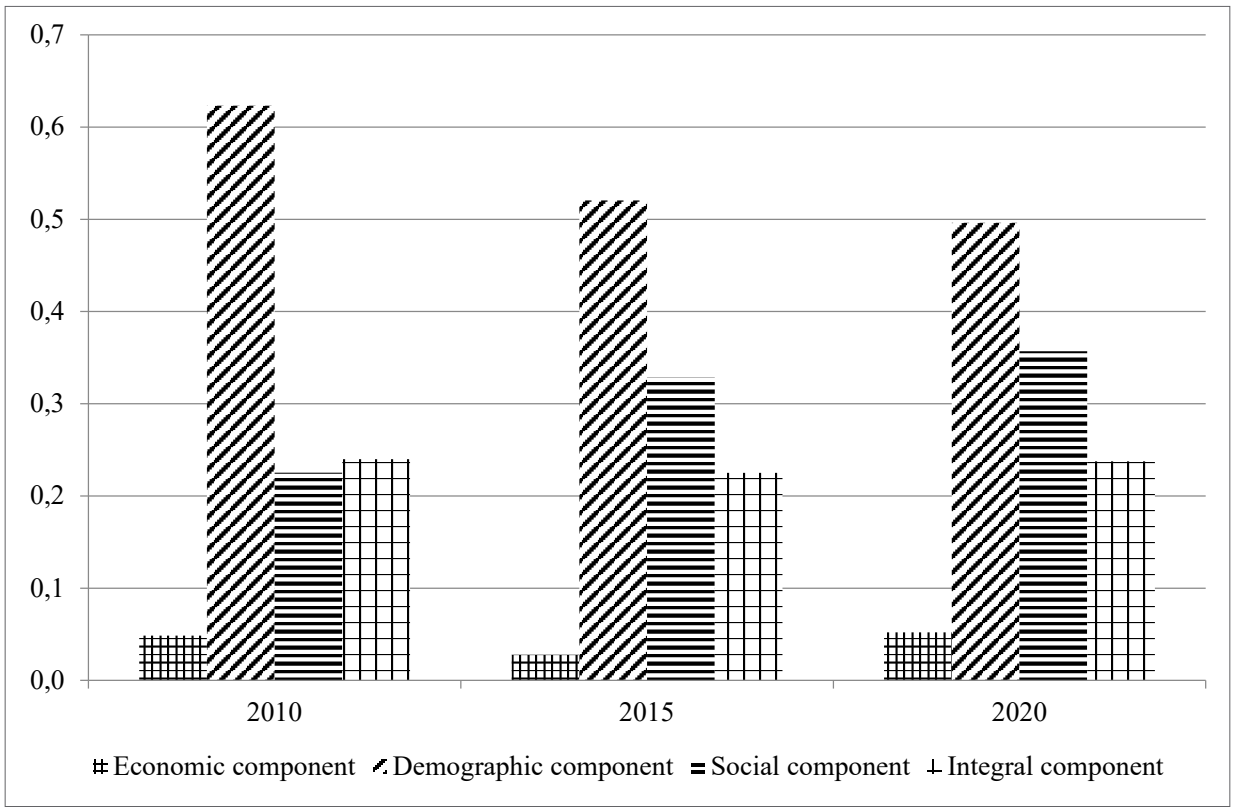

Figure 2. Integral assessment of the security of the population and its constituents in Ukraine
Source: calculated by the authors

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ІНТЕГРАЛЬНЕ ОЦІНЮВАННЯ РІВНЯ БЕЗПЕКИ НАСЕЛЕННЯ КРАЇНИ

Анотація. *Перед сучасною економікою України постали надважкі виклики, у більшості обумовленні війною, які вимагають швидкого та адаптивного реагування. Мілітаризація економіки, фінансові витрати, міграція обумовили чисельні «економічні шоки» та кризи національної господарської системи. Починаючи з 2014 року і по цей день, Україна бореться за свою незалежність, проте така боротьба є вкрай важкою та ресурсовитратною. Існує необхідність підтримки безпеки не лише у військовому відношенні, але й економічному, промисловому, фінансовому тощо. Людські ресурси є тим джерелом, яке спроможне підтримати безпеку у різних секторах та галузях економіки. Тому оцінювання рівня безпеки населення є важливим питанням сучасності, яке потребує більш глибокого вивчення.*

Інформаційним джерелом нашого дослідження є данні інтернет-ресурсу http://data.un.org/, завдяки якому нами залучено значний масив статистичних показників для оцінювання рівня безпеки населення. В статті використані методи математичного моделювання, аналізу та статистичного порівняння. Для інтегрального оцінювання рівня безпеки населення країни використовувалася система статистичних показників, що відображають її економічні, демографічні та соціальні аспекти. На основі цих показників розроблена єдина інтегральна оцінка. Така оцінка дає можливість порівняти стан безпеки населення в різних країнах та виявити тенденцію розвитку безпеки у визначеній країні.

Апробація запропонованої методики була реалізована на прикладі 27 країн світу: України, Польщі, Вірменії, Азербайджану, Болгарії, Хорватії, Чехії, Естонії, Грузії, Угорщини, Казахстану, Киргизстану, Латвії, Литві, Республіки Молдови, Австрії, Бельгії, Німеччини, Греції, Данії, Ірландії, Іспанії, Італії, Кіпру, Мальти, Франції, Швеції. Результати практичного використання методики для розрахунку рівня безпеки населення за обраними країнами, показали, що найвищу безпеку на 2020 рік мали Данія, Ірландія та Швеція, а найнижчу Україна, Азербайджан та Казахстан.

Запропонована методика інтегральної оцінки безпеки населення дозволяє оцінити рівень безпеки не тільки в окремо взятій країні світу, але й порівняти цей показник з іншими. Зазначене дозволить зацікавленим особам здійснювати моніторинг безпеки населення, визначати її проблеми та розробляти адаптивні заходи з її підвищення. Особливо важливе значення має дана методика для країн з нестабільним інституціональним середовищем, діючими військовими конфліктами та несприятливою ринковою кон'юнктурою.

Ключові слова: *безпека, населення, безробіття, біженці, тривалість життя, платіжний баланс, охорона здоров'я, освіта*

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MODELLING A COMPREHENSIVE ASSESSMENT OF THE LEVEL OF INNOVATION SECURITY

Abstract. *The assessment of the level of innovation security is an important task to ensure socio-economic or innovative development and support scientific and technological progress. At the same time, in the modern scientific world, there are not enough methods that allow carrying out an accurate diagnosis of innovation security. It is relevant to consider in such diagnostics the system of external and internal factors that stimulate, or on the contrary, hinder innovative development. An important issue is to improve the tools, methods and stages of such an assessment, taking into account the present.*

The study used a system of methods and tools that allowed solving the problems of the article: mathematical modelling, correlation and regression analysis, modified principal component, Holt's adaptive model, abstraction, synthesis, deduction and induction. The database used for modelling the integrated assessment of innovation security is an official statistical sources, which reflect the results of innovation activity.

It has been proved that innovation activity plays an important role both in the effective functioning of individual sectors of the economy and in the social development of the country as a whole. Consequently, such activity requires constant monitoring and evaluation. The methodology of diagnostics of the level of innovation security and its forecast is proposed.

The obtained levels of innovation security, as well as the forecast, indicate the increased need to form a new type of state policy, which will completely restart innovation activity. The proposed methodology will be useful for the interested market players, which is important to diagnose the current state of innovation activity in time, as well as to develop a policy for innovative development of the country for the future.

Keywords: *innovation, security, socio-economic development, scientific and technological works, globalisation, state budget, gross domestic product.*

1. Introduction

Innovations are the key to the socio-economic development of any country in the world. It is innovations that encourage business entities and the state as a whole to develop. Innovations play a special role in the conditions of globalisation and accelerated competition. It is scientifically proven that countries with high innovative development have highly developed industries, agro- sector and the standard of living of the population in such countries is known to be higher in comparison with innovatively backward economies of other countries. The assessment of the level of innovation security is of high importance, which allows timely identification of threats coming from the external environment. Due to timely diagnostics of the level of innovation security, it is possible to prevent negative consequences for the production of innovations and to develop an effective state innovation policy.

The aim of the article is to determine the methodology for assessing the level of innovation security taking into account today's conditions.

Modelling of complex assessment of the level of innovation security is not a widespread enough topic in scientific sources. The authors paid more attention to the methodology of integrated assessment of the functioning of the state, enterprises, innovative development, economic security etc. In particular, Sukhorukov and Kharazishvili, [1], focused their attention on modelling the assessment of the components of economic security of the state. The study proposed a macroeconomic model for identifying the impact of destabilising factors on the development of the state. Shchurov, [2], at a high scientific level carried out the process of diagnosing the level of economic security of the oil and gas industry. Shchurov, [2], established the level of economic security of the enterprise, identified trend changes at the end of the research period and demonstrated the importance of the dualism of interaction between the enterprise and the state in terms of economic and energy security. The author used modern scientific methods of research-taxonomic analysis and fuzzy set theory Kobeleva and Pererva, [3], proposed a methodological concept of monitoring energy security indicators in the activity of business structures, determined the meaningful sequence of stages of monitoring the financial, production and commercial activities of an industrial enterprise, developed methodological provisions of monitoring of energy security of industrial enterprise using monitoring functions. Prokopenko *et al.,* [4], analysed the influence of state policy on the economic security of machine-building complex, assessed the impact of the state decision on certain elements of the system of public procurement Prozorro, etc. Krupka and Kostetsky, [5], determined the impact of public and private partnerships on strengthening the financial security of economic entities, identified the problems of security support, noted the need to reform the current legislation to simplify the procedure for attracting business entities to participate in public and private partnership projects Shaulskaya and Shcherb, [6], defined the human-centric model of security in the context of preventing risks and conflicts in the social, labour and entrepreneurial spheres, identified the importance of economically safe behaviour of employees in reducing threats to the economic security of the enterprise, detailed the central drivers and threats to economic security at the private level, allowing the formation of an ecosystem for preventing threats of conflicts. Chubaevsky, [7], proposed methods of corporate information security management, generalised scientific approaches to the formation of the mechanism of economic security of the enterprise, defined the scientific basis for the development of the mechanism of formation of corporate information security, the elements of which are objects, subjects, goal, functions and methods. Bartosova *et al.,* [8], proposed non-standard methods for assessing the effectiveness of strategic change management of companies in the system of open innovation. Some modelling tools are appropriate for use in our research. Kopylyuk and Zhuribida, [9], proposed a comprehensive approach to assessing the level of economic security of banks in Ukraine, based on grouping institutions by level of economic security identified threats and dangers accompanying the activities of banks in the context of the state, foreign banking groups and private capital. Kopteva, [10], proposed the author's model for assessing the economic security of business processes of a trading enterprise, allowing thoroughly carrying out calculations and making effective management decisions to ensure the economic security of the enterprise. Yarova, [11], developed a methodology for assessing national security in the context of the principles of sustainable spatial development, proposed indicators of forest security and considered the methodology of forming an algorithm for building a comprehensive rating assessment of national security components.

Paying due respect to the scientific developments of the authors, we note some fragmentation in the consideration of the process of assessing the level of innovation security. In the framework of our study, it will be useful to use the tools, methods and methodologies of the above authors, which can be partially adapted to our study.

2. Materials and Methods

Innovation activity plays an important role both in the development of individual sectors of the economy and in the economic development of the country as a whole. For a comprehensive assessment of the level of innovation security, it is necessary to use a variety of indicators reflecting various aspects of innovation activity. Let us note through $Q = \{q_i\}_{i=1}^{n}$ set of these indicators. For each indicator q_i, it is possible to determine the critical value q_i^{kr} and optimal value q_i^{opt}. The list of characteristics from the set Q is given in Table 1.

To study the dynamics of these indicators we used statistical data for the retrospective period

Table 1

Indicators for assessing the level of innovation security

Indicator	Sense of the indicator	Critical value	Optimal value
q_1	Gross fixed capital formation as a percentage of GDP	18	30
q_2	Percentage of products sold on competitive markets of the country	50	80
q_3	Share of R&D activities in GDP (in per cent)	0,5	3
q_4	Ratio of state budget expenditures on R&D to GDP (in per cent)	0,2	1
q_5	Percentage of enterprises that implemented innovations	5	35
q_6	Share of innovative products sold (in per cent)	3	25
q_7	Number of specialists performing scientific and technical work per thousand employed population	5	22

Source: Combination of indicators proposed by the authors

2010–2020. Let us denote the value of indicator q_i, in the t-th year of the retrospective period through $q_i(t)$. The values of indicators q_i, during the retrospective period are given in Table 2.

During the retrospective period, none of the indicators reached the optimal value. The indicator q_1 of gross fixed capital formation in relation to GDP grew during 2010–2012 and in 2012 exceeded the critical value of 18%. In 2013–2015, there was a decrease in this indicator and in 2016–2018, it increased again, although its value remained less than the critical value. In 2019, the value of this indicator remained almost unchanged and in 2020, it decreased significantly. The highest chain growth rate was achieved in 2016 and the lowest in 2020.

The indicator q_2 of the part of products sold on competitive markets remains below the critical value of 50% throughout the entire retrospective period, although in 2010–2012 it approached its value. The most significant decrease in this indicator occurred in 2015 — by 10% less than the previous year.

The indicator q_3 of the part of performed scientific and scientific-technical works in GDP exceeded the critical value in 2010–2017, but starting from 2017 its value decreased and became less than the critical value in 2019–2020.

The indicator q_4 — ratio of state budget expenditures on scientific and scientific-technical works to GDP has been decreasing since 2013 (except for 2018, when budget expenditures on innovation increased by 2.8 times compared to the previous year). In 2017, 2019 and 2020, the values of this indicator became less critical, and in 2020, they reached the minimum value for the entire period.

The percentage of enterprises that introduced innovations (indicator q_5) during the whole retrospective period significantly exceeded the critical value of 5%, with periods of growth of this indicator alternating with periods of decline.

The share of realised innovative products (indicator q_6) by 2017 had a clearly pronounced downward trend, because of which, starting from 2014, the value of this indicator becomes less than critical. The decrease in this indicator was particularly significant in 2014 and 2017. In the period 2018–2020, this indicator increases, although it does not reach the value of 2014.

The number of professionals performing S&T work per thousand-employed population (indicator q_7) decreased between 2015 and 2019, resulting in a less-than-critical value in 2019.

To determine the interrelationships between the indicators from the set Q, we determine the correlation coefficients $r_{ij} = r\left(q_i, q_j\right)$ between these indicators. These coefficients form a correlation matrix:

$$R = (r_{ij})_{i,j=1}^{7} =$$

$$= \begin{pmatrix} 1,000 & 0,300 & 0,335 & 0,672 & 0,252 & 0,377 & -0,400 \\ 0,300 & 1,000 & 0,798 & 0,674 & 0,498 & 0,899 & -0,316 \\ 0,335 & 0,798 & 1,000 & 0,776 & 0,442 & 0,708 & -0,112 \\ 0,672 & 0,674 & 0,776 & 1,000 & 0,430 & 0,676 & -0,350 \\ 0,252 & 0,498 & 0,442 & 0,430 & 1,000 & 0,338 & 0,201 \\ 0,377 & 0,899 & 0,708 & 0,676 & 0,338 & 1,000 & -0,521 \\ -0,400 & -0,316 & -0,112 & -0,350 & 0,201 & -0,521 & 1,000 \end{pmatrix}$$

Table 2

Dynamics of innovation security indicators

Indicator	Years										
	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
q_1	16,98	17,42	19,54	17,63	14,00	13,50	15,20	15,76	17,65	17,61	13,37
q_2	48,30	49,80	49,20	45,70	47,50	42,70	43,40	41,90	40,73	39,56	42,00
q_3	0,82	0,73	0,75	0,77	0,66	0,67	0,70	0,60	0,55	0,48	0,45
q_4	0,34	0,29	0,33	0,33	0,26	0,21	0,20	0,15	0,29	0,19	0,09
q_5	13,90	16,20	17,40	16,80	16,10	15,20	16,60	14,30	15,60	13,80	14,90
q_6	3,80	3,80	3,30	3,30	2,50	1,40	1,30	0,70	0,80	1,30	1,90
q_7	3,70	5,40	5,20	4,90	4,90	7,45	6,02	5,84	5,39	4,78	4,95

Source: calculated by the authors using https://www.ukrstat.gov.ua/

The significance of the obtained correlation coefficients is checked by the Student's criterion. The correlation coefficient is considered significant if the actual value of this criterion obtained by the formula:

$$t_{факт}(i,j) = \sqrt{\frac{r_{ij}^2}{1-r_{ij}^2}(T-2)} \quad (1)$$

where T is the duration of the retrospective period (T = 11), exceeds the tabulated value $t(\alpha,k)$ which corresponds to the confidence probability α and the number of degrees of freedom $k = T - 2$. Taking the value of confidence probability $\alpha = 0{,}95$, we obtain that $t(\alpha,k) = 2{,}362$. Inequality $t_{actual}(i,j) > t(\alpha,k)$ is fulfilled when the correlation coefficient $r_{ij} > 0{,}602$.

Thus the correlation coefficients $r_{14} = 0{,}672$, $r_{23} = 0{,}798$, $r_{24} = 0{,}674$, $r_{26} = 0{,}899$, $r_{34} = 0{,}766$, $r_{36} = 0{,}788$ and $r_{46} = 0{,}676$. Consequently, the indicators of the ratio of state budget expenditures on scientific and scientific-technical works to GDP, the percentage of products sold in the competitive markets of the country, the share of performed scientific and scientific-technical works in GDP and the share of sold innovative products are significantly correlated with each other, in addition, the indicator of the ratio of state budget expenditures on scientific and scientific-technical works to GDP is correlated with the indicator of gross fixed capital formation as a percentage of GDP. The indicators of the percentage of enterprises that introduced innovations and the number of specialists performing scientific and technical work per thousand-employed population do not correlate with other indicators of the set Q.

3. Results and Discussion

Let us define an integral assessment of innovation security, which includes all indicators q_i, and reflects the existing relationships between them. To obtain such an assessment, let us transform these indicators in such a way that their values refer to the interval [0,1].

Let's mark through q_i^{min} and q_i^{max} respectively the minimum and maximum elements of the set $\{q_i(t)\}_{t=1}^{T} \cup \{q_i^{kr}, q_i^{opt}\}$. Integral evaluation $G(t)$ of innovation activity in the t-th year of the retrospective period is determined by the formula:

$$G(t) = \sum_{i=1}^{7} \alpha_i \frac{q_i(t) - q_i^{min}}{q_i^{max} - q_i^{min}} \quad (2)$$

where α_i weight coefficients of indicators. These coefficients are determined by the modified principal component method, which makes it possible to take into account significant correlations between the indicators included in the integral assessment.

To determine the weighting coefficients we make a covariance matrix $K = (k_{ij})$, whose elements are the covariance coefficients k_{ij} between indicators g_i and g_j the values of which are determined by the formulas:

$$g_i(t) = \frac{q_i(t) - q_i^{min}}{q_i^{max} - q_i^{min}} \quad (3)$$

$$g_j(t) = \frac{q_j(t) - q_j^{min}}{q_j^{max} - q_j^{min}} \quad (4)$$

The covariance matrix K has the following form:

$$K = \begin{pmatrix} 0{,}0134 & 0{,}0030 & 0{,}0017 & 0{,}0067 & 0{,}0011 & 0{,}0020 & -0{,}0023 \\ 0{,}0030 & 0{,}0073 & 0{,}0031 & 0{,}0050 & 0{,}0016 & 0{,}0036 & -0{,}0013 \\ 0{,}0017 & 0{,}0031 & 0{,}0020 & 0{,}0030 & 0{,}0008 & 0{,}0015 & -0{,}0002 \\ 0{,}0067 & 0{,}0050 & 0{,}0030 & 0{,}0074 & 0{,}0014 & 0{,}0027 & -0{,}0014 \\ 0{,}0011 & 0{,}0016 & 0{,}0008 & 0{,}0014 & 0{,}0015 & 0{,}0006 & 0{,}0004 \\ 0{,}0020 & 0{,}0036 & 0{,}0015 & 0{,}0027 & 0{,}0006 & 0{,}0022 & -0{,}0012 \\ -0{,}0023 & -0{,}0013 & -0{,}0002 & -0{,}0014 & 0{,}0004 & -0{,}0012 & 0{,}0024 \end{pmatrix}$$

When applying the modified principal component method, the weight coefficients α_i in the integral estimation are taken equal to the squares of the component of the eigenvector of this matrix, which corresponds to the maximum eigenvalue of this matrix.

To determine the eigenvalues of the matrix K we solve the equation:

$$\det(K - \lambda E) = 0$$

where E is a unit matrix of the seventh order, and $\det(K - \lambda E)$ — determinant of the matrix $K - \lambda E$.

The maximum root of this equation is $\lambda_{max} = 0{,}0227$. This root is 63% of the sum of all roots of the equation. Consequently, the integral score obtained by the modified principal component method reflects with sufficient accuracy the influence of all the indicators involved in its creation. To determine the eigenvector W corresponding to the eigenvalue λ_{max}, we find a non-zero solution of the equation

$$KW = \lambda_{max} W .$$

The defined components w_i of the eigenvector W and the corresponding weighting coefficients α_i in the integral innovation score are summarised in Table 3.

Consequently, the integral assessment of innovation activity is as follows:

$$G = 0{,}4169g_1 + 0{,}1718g_2 + 0{,}0461g_3 + 0{,}2754g_4 + \\ + 0{,}0128g_5 + 0{,}0545g_6 + 0{,}0224g_7$$

Table 3

Components of the eigenvector W and weighting coefficients of the integral assessment of innovation activity

i	w_i	Coefficient α_i
1	0,6457	0,4169
2	0,4145	0,1718
3	0,2147	0,0461
4	0,5248	0,2754
5	0,1133	0,0128
6	0,2335	0,0545
7	0,1495	0,0224

Source: proposed by the authors

Table 4

Integral assessments of innovation security

Year	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Score	0,221	0,225	0,287	0,224	0,116	0,068	0,110	0,098	0,182	0,144	0,019

Source: calculated by the authors

Using the relationship between indicators g_i and q_i it is possible to express the integral score of G through indicators q_i:

$$G = 0,0251q_1 + 0,0042q_2 + 0,0181q_3 + 0,3018q_4 + \\ +0,0004q_5 + 0,0022q_6 + 0,0012q_7 - 0,5458$$

The integral estimates obtained using this equality are presented in Table 4.

The dynamics of the integral assessment of innovation security is reflected in Figure 1.

To obtain forecast values of indicators q_i for 2023–2024, we use different forecasting models, the choice of which is determined by the peculiarities of the dynamics of these indicators in the retrospective period.

For forecasting indicators q_1, q_2, q_3, q_5 and q_7 we use Holt's adaptive model.

In Holt's model, the adaptation process is ensured by using the smoothing coefficient of the dynamic series γ and the smoothing coefficient of the trend δ. The values of these coefficients are chosen empirically to ensure the highest forecast accuracy.

When using the Holt model to predict the indicator q_i, at each year of the retrospective period, the values of $a_i(t)$ of the exponential-smoothed series and the value of $b_i(t)$ of the trend.

At $t = 1$, the value $a_i(1)$ of the exponentially smoothed series is taken to be equal to the value of the indicator q_i in the first year of the retrospective period, and the value $b_i(1)$ of the trend is taken to be equal to 0.

For other values of t, we calculate these values by recurrence formulas:

$$a_i(t) = \gamma q_i(t) + (1-\gamma)(a_i(t-1) + b_i(t-1)) \quad (5)$$

$$b_i(t) = \delta(a_i(t) - a_i(t-1)) + (1-\delta)b_i(t-1) \quad (6)$$

Forecast values of indicators q_i for j years are determined from the equality:

$$q_i(T+j) = a_i(T) + jb_i(T) \quad (7)$$

where T is the number of years in the retrospective period. Forecast accuracy is assessed using the absolute error Δ_i and relative error ε_i, which are calculated for each year of the retrospective period using the following formulas:

$$\Delta_i(t) = q_i(t) - a_i(t) - b_i(t) \text{ and } \varepsilon_i(t) = \frac{\Delta_i^2(t)}{q_i^2} \quad (8)$$

Forecast accuracy is estimated by the value ν_i, determined from the equality:

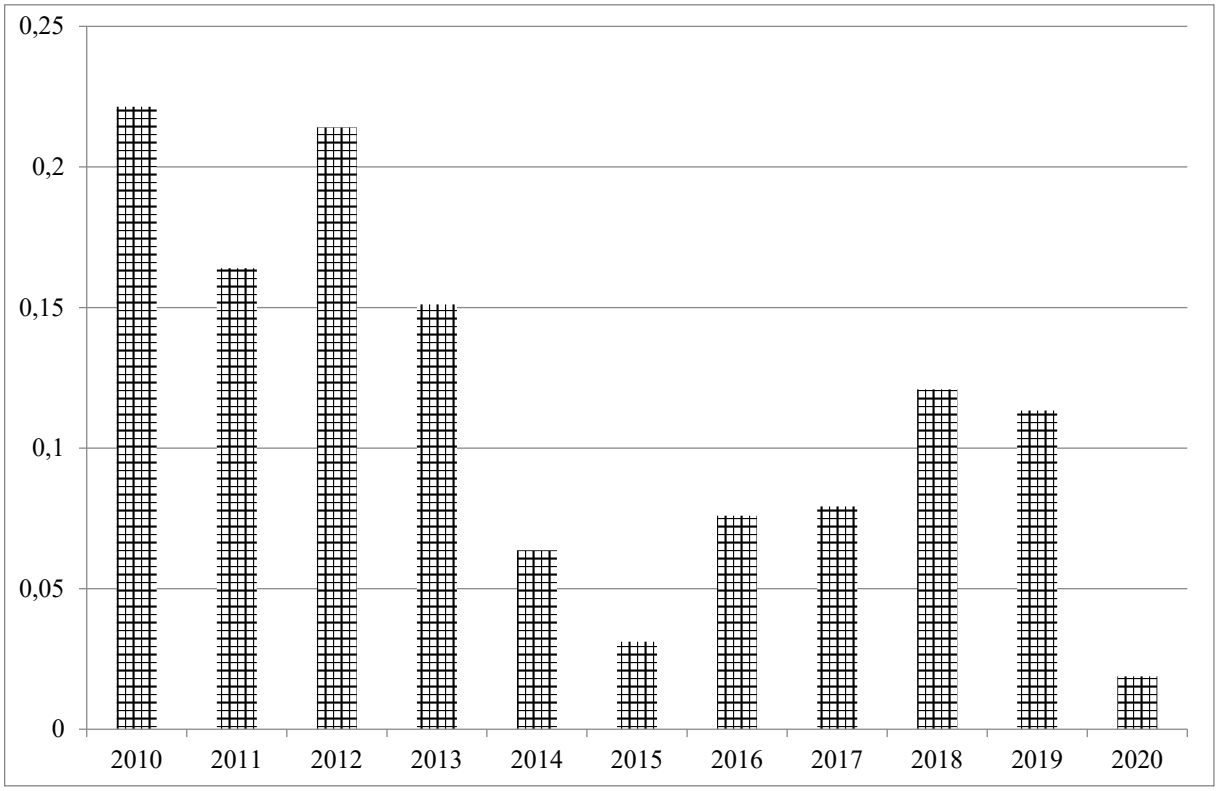

Figure 1. Dynamics of the integral assessment of innovation security

Source: calculated by the authors

$$\nu_i = 1 - \frac{\sum_{t=2}^{T} \varepsilon_i(t)}{T-1} \quad (9)$$

In predicting the values of indicators q_1, q_2, q_3, q_5 and q_7, the prediction accuracies were 97,95%, 99,73%, 99,27%, 98,97% and 96,46% respectively.

To forecast the values of indicators q_4, and q_6 we use the exponential levelling model. This model includes the parameter θ, which determines the advantage of newer values of the indicator in obtaining forecasts. This parameter belongs to the segment [0.2; 0.6], its value is chosen empirically. When forecasting the indicator q_4 we have chosen the value $\theta = 0.5$, and when forecasting the indicator q_6 — the value $\theta = 0.28$. To approximate the value of the predicted indicator, we use a second-order polynomial:

$$\varphi(t) = \eta_0 + \eta_1 t + \eta_2 \frac{t^2}{2!} \quad (10)$$

the coefficients of which we determine by the method of least squares.

Further, for all values of t, corresponding to the years of the retrospective period, we determine the elements of $q_i^1(t)$, $q_i^2(t)$, $q_i^3(t)$ of the aligned series. At $t = 1$ we use the formulas:

$$\begin{cases} q_i^1 = \eta_0 - \frac{1-\theta}{\theta}\eta_1 + \frac{(1-\theta)(2-\theta)}{2\theta^2}\eta_2 \\ q_i^2 = \eta_0 - \frac{2(1-\theta)}{\theta}\eta_1 + \frac{2(1-\theta)(3-2\theta)}{2\theta^2}\eta_2 \\ q_i^3 = \eta_0 - \frac{3(1-\theta)}{\theta}\eta_1 + \frac{3(1-\theta)(4-3\theta)}{2\theta^2}\eta_2 \end{cases} \quad (11)$$

For values $t > 1$ quantities $q_i^1(t)$, $q_i^2(t)$, $q_i^3(t)$ are denoted by recurrence formulas:

$$\begin{cases} q_i^1(t) = (1-\theta)q_i^1(t-1) + \theta q_i(t) \\ q_i^2(t) = (1-\theta)q_i^2(t-1) + \theta q_i^1(t) \\ q_i^3(t) = (1-\theta)q_i^3(t-1) + \theta q_i^2(t) \end{cases}. \quad (12)$$

In this case, the values of η_0, η_1 and η_2 also change according to the formulas:

$$\begin{cases} \eta_0 = 3q_i^1(t) - 3q_i^2(t) + q_i^3(t) \\ \eta_1 = \frac{\theta}{2(1-\theta)^2}[(6-5\theta)q_i^1(t) - 2(5-4\theta)q_i^2(t) + (4-3\theta)q_i^3(t) \\ \eta_2 = \frac{\theta^2}{(1-\theta)^2}(q_i^1(t) - 2q_i^2(t) + q_i^3(t) \end{cases} \quad (13)$$

The values of η_0, η_1 and η_2 obtained at $t = T$ are used to determine the forecasted value of the q_i indicator:

$$q_i(T+j) = \eta_0 + \eta_1 j + \eta_2 \frac{j^2}{2!} \quad (14)$$

The determined forecast values of q_i indicators for 2023–2024 are shown in Table 5.

Consequently, a certain increase in the ratio of state budget expenditures on scientific and scientific-technical works to GDP is forecasted, this indicator is expected to reach the critical value of 0.2. In 2024, the share of realised innovative products is forecast to grow, although the value of this indicator will remain less than the critical. For the rest of the indicators considered, a decrease is forecasted compared to the 2020 level. At the same time, of all these indicators, only the percentage of enterprises implementing innovations will remain above the critical value.

4. Conclusions

Thus, we have determined that innovation activity plays an important role in the effective functioning of individual sectors of the economy, as well as in the social development of the country as a whole. For a comprehensive assessment of the level of innovation security, it is necessary to use many indicators reflecting various aspects of innovation activity. The greatest decrease in innovation security was determined in 2020, and its highest value, respectively, in 2010. The obtained levels of innovation security, as well as its forecast, indicate the increased need for the formation of a new type of public policy, which will completely restart innovation activity.

Table 5

Forecast values of innovation activity indicators

Indicator	Sense of the indicator	Forecast for 2023	Forecast for 2024
q_1	Gross fixed capital formation as a percentage of GDP	12,34	11,68
q_2	Percentage of products sold on competitive markets of the country	40,45	40,17
q_3	Share of completed scientific and technical works in GDP (in per cent)	0,31	0,27
q_4	Ratio of state budget expenditures on R&D to GDP (in per cent)	0,20	0,20
q_5	Percentage of enterprises that implemented innovations	13,39	13,09
q_6	Share of innovative products sold (in per cent)	1,60	2,09
q_7	Number of specialists performing scientific and technical work per thousand employed population	4,72	4,64

Source: calculated by the authors

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МОДЕЛЮВАННЯ КОМПЛЕКСНОГО ОЦІНЮВАННЯ РІВНЯ ІННОВАЦІЙНОЇ БЕЗПЕКИ

Анотація. *Оцінювання рівня інноваційної безпеки є важливим заданням забезпечення соціально-економічного або інноваційного розвитку та підтримки науково-технічного прогресу. Одночасно у сучасному науковому світі недостатньо методик, які дозволяють провести точну діагностику інноваційної безпеки. Актуальним є врахування в такій діагностиці системи зовнішніх та внутрішніх чинників, які стимулюють або навпаки заважають інноваційному розвитку. Важливим питанням є удосконалення інструментарію, методів та етапів такого оцінювання з урахуванням сьогодення.*

В дослідженні використано система методів та інструментів, які дозволили вирішити задачі статті: математичного моделювання, кореляційно-регресійного аналізу, модифікованої головної компоненти, адаптивна модель Хольта, абстрагування, синтезу, дедукції та індукції. Базою даних, яка використовувалася для моделювання комплексного оцінювання інноваційної безпеки є офіційні статистичні джерела, в яких відображені результати інноваційної діяльності.

Доведено, що інноваційна діяльність відіграє важливу роль як в ефективному функціонуванні окремих галузей економіки, так і в соціальному розвитку країни в цілому. Отже така діяльність вимагає постійного моніторингу та оцінювання. Запропоновано методику діагностики рівня інноваційної безпеки та його прогнозу.

Отримані рівні інноваційної безпеки, а також прогноз засвідчують підвищену необхідність формування державної політики нового типу, яка повністю перезапустить інноваційну діяльність. Запропонована методика буде корисною для зацікавлених суб'єктів ринку, яким важливо вчасно діагностувати поточний стан інноваційної діяльності, а також розробляти політику інноваційного розвитку країни на перспективу.

Ключові слова: *інновації, безпека, соціально-економічний розвиток, науково-технічні роботи, глобалізація, держбюджет, валовий внутрішні продукт.*

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MODELING THE RELATIONSHIP BETWEEN THE COUNTRY'S ECONOMIC DEVELOPMENT AND NATIONAL TOURISM

Abstract. *Tourism occupies an important place in the socio-economic development of any country and the improvement of its competitive position on the world stage. Effectively working tourism sectors contribute to the creation of new jobs, fill budgets at all levels, attract investments in infrastructure, help preserve or restore cultural and historical monuments, and also stimulate the involvement of the population in traditional arts and innovative crafts. In this case, a thorough study of the functioning of the tourist sector of the economy, as well as determining its contribution to the macroeconomic development of the country, is of particular importance. Analyzing trends or relationships between a country's macroeconomic development and tourism flows can help better understand how tourism affects a country's economy.*

To solve the problems of our research, we analyzed such indicators as: seasonality indices of outbound and domestic tourists; gross domestic product per person; the number of tourists served by tour operators and travel agents, etc. In the process of analysis, we used production function modeling methods, regression and correlation analyses, and separate built-in statistical functions in the "Statistica" software resource.

Based on the simulation results, we obtained numerical production functions, regression equations, and models that allowed us to determine the dependence and influence of tourist flows on the main macroeconomic indicator of the country. The specified method of analyzing the dependence of the gross domestic product on tourist flows is the basis for further forecasting of the outlined trends.

The interdependence of the index of seasonality and the gross domestic product per person using economic and mathematical methods and models proves the ambiguity in the conclusions and descriptions of the resulting modeling. After all, the flow of tourists during the calendar year depends on many factors and tourist preferences, can affect both the overall production of the gross domestic product and other macro indicators of the national economy.

Keywords: *tourist activity, tourist flows, tour operators, travel agents, gross domestic product, production functions, seasonality index.*

1. Introduction

The country's macroeconomic development and tourism have a deep relationship, since tourism can affect the main indicators of macroeconomic activity, such as gross domestic product, employment, investments, and others. Tourism can become an important component of filling the country's gross domestic product due to direct and indirect costs of tourists. An increase in the tourist flow can lead to an increase in socio-economic development, an increase in the attractiveness of the country and an increase in the welfare of the population. The development of the tourism industry can create new jobs in the service sector, construction and other areas related to tourism. This can have a positive effect on the level of employment in the country. Tourism can improve the country's foreign economic relations by increasing the international exchange of goods and services, as well as by attracting foreign investment. In general, tourism can play an important role in the macroeconomic development of a country, but it is important to ensure the sustainability of development and its balance with other sectors of the economy to avoid negative consequences such as overpopulation, environmental degradation and cultural degradation. In the context of the above, the study of the relationship between the macroeconomic development of the country and tourism is of great importance. Irtischeva *et al.*, [1], identified the problems of macroeconomic aspects of the development of the tourism industry in Ukraine and the peculiarities of their regulation. The researchers rightly noted that our country has all the prerequisites for the intensive development of various areas of tourist activity, and the territorial concentration of tourist enterprises reflects the structure of demand and depends on the well-being of the population of the region. Ostapyuk, [2], investigated the impact of the macroeconomic situation on the development of tourism in Ukraine and specified the specifics of its functioning. Lendel and Morohovych, [3], determined the impact of the macroeconomic situation on the development of the tourism industry of the Transcarpathian region. Lebedeva, [4], analyzed the impact of the macroeconomic situation on the development of the tourism sector of Ukraine. Nakonechnyi *et al.*, [5], Tsyganchuk, [6], proposed mathematical and statistical modeling tools that can be used within our scientific research. Of particular interest to us are the scientific studies of Zhang *et al.*, [7], which focus on the issues of balanced consumption, resource conservation, and the efficiency of using mineral resources, human capital, and tourism. Portella-Carby *et al.*, [8], described in detail the cause-and-effect relationships between economic growth and tourism using the example of business cycles in Europe for the period 1995–2021. Interesting are the scientific findings of Calero and Turner, [9], Dogan and Zhang, [10], which analyzed the effects of tourism on sustainable development and changes in macroeconomic indicators of the country. A research paper by Wickramasinghe and Naranpanawa, [11], identifies how the pandemic has affected hospitality and tourism. Nag and Sarkar, [12], proposed tools for forecasting tourism demand and transport infrastructure. The noted scientific studies undoubtedly have a significant contribution to the theory and practice of macroeconomic development and the analysis of complex socio-economic processes, namely tourist flows. However, the problem of analyzing the country's macroeconomic development and tourist flows, taking into account the present, needs a more thorough analysis.

2. Materials and Methods

Production functions play a conceptual role in determining efficiency, optimal use of resources, and forecasting cash and human flows in tourism. Forecasting using production functions allows predicting the amount of tourism services that can be provided using available resources for a certain area. This helps business entities in the tourism sector and infrastructure organizations to plan their activities according to their own potential and effectively manage resources. Modeling production functions helps to determine the directions of optimal use of labor, capital and other assets (location of hotels, transport logistics, size and composition of management teams, etc.). Production functions play an important role in determining the effectiveness of investments in tourism infrastructure, the relationship between service costs and profit. Economic-statistical modeling of production functions shows regularities or dynamics of dependence between target indicators of the tourism industry, production of products, gross industrial product of the country, and so on. Therefore, we can state the great epistemological, methodological and practical importance of modeling production functions, since their mathematical expression contains the result of the interrelationship of factors and results of the tourism market, which can be interpreted at the macro-, meso- and microeconomic levels. In order to study tourist flows using production functions, we used data from the statistical reporting of Ukraine for 2015–2021. Linear and non-linear production functions will help to investigate the dependence of gross domestic product per person on the seasonality index of outbound and domestic tourists for the period under analysis. Taking into account these factors and the macroeconomic indicator, we believe that the seasonality of tourist activity, among other factors, directly affects the gross domestic product. Precisely, these judgments led us to a deeper study, analysis and modeling of the impact of tourist flows on the gross domestic product.

We briefly justify the choice and properties of research factors — indices of seasonality of outbound and domestic tourists. In statistics, the most widespread method of calculating the seasonality

Table 1

Dynamics of the index of seasonality of outbound and domestic tourists and the effective indicator of gross domestic product per person, 2015–2021.

Years	Index of seasonality of outbound tourists	Index of seasonality of domestic tourists	Gross domestic product per person, UAH
2015	2,13	1,90	46413,00
2017	1,90	1,80	70170,00
2018	1,46	1,88	84228,00
2019	1,21	1,74	94633,00
2020	2,05	2,35	101138,00
2021	1,87	2,24	131734,00

Source: supplemented by the author taking into account the source https://www.ukrstat.gov.ua/

index is the determination of the average level of the indicator for months, years, which is taken to compare temporal data with the average level as a whole. This index is calculated as a percentage. The material for the study will be the dynamic series of the main factors of the index of seasonality of outbound and domestic tourists and the effective indicator of the gross domestic product per person for the last 2015–2021 (Table 1).

In our study, the main purpose of regression modeling and calculation of the obtained coefficients is to determine the production function. Such a function indicates the connection between the performance indicator and the factors, which will allow modeling of complex socio-economic phenomena in the future. We will define production regression models that we will use in our research for statistical processing.

Thus, the classic linear production regression is generally represented by the equation (Nakonechnyi *et al.*, [5]):

$$Y = a_1 X + a_0 \quad (2)$$

Non-linear production regressions are expressed as (Nakonechnyi *et al.*, [5]):

$$Y = a_1 / X + a_0 \quad (3)$$

$$Y = a_1 \ln X + a_0 \quad (4)$$

$$Y = a_1 / \ln X + a_0 \quad (5)$$

$$Y = a_1 e^X + a_0 \quad (6)$$

$$Y = a_1 / \sqrt{X} + a_0 \quad (7)$$

$$Y = a_1 \sqrt{X} + a_0 \quad (8)$$

$$Y = a_1 / X^2 + a_0 \quad (9)$$

$$Y = a_1 X^2 + a_0 \quad (10)$$

$$Y = a_1 / X^3 + a_0 \quad (11)$$

$$Y = a_1 X^3 + a_0 \quad (12)$$

$$Y = \frac{1}{a_1 X + a_0} \quad (13)$$

$$Y = a_1 \sqrt[3]{X} + a_0 \quad (14)$$

$$Y = a_1 / \sqrt[3]{X} + a_0 \quad (15)$$

$$Y = a_1^X a_0 \quad (16)$$

$$Y = X^{a_1} a_0 \quad (17)$$

To calculate and process data on the dependence of the gross domestic product per person on the declared factors for the analysis of the tourism sector, we use the "Statistica" software resource and built-in statistical functions.

3. Results and Discussion

For further analysis of tourist flows, the influence of each factor on the value of gross domestic product per person was calculated using linear and non-linear functions for 2015–2021. In the course of mathematical transformations and static calculations, linear production regression and non-linear production regressions of gross domestic product were obtained per person, which are presented in Table 2.

Therefore, the obtained production regression models of the gross domestic product per person for the last six years help to determine the quality and their adequacy, which will allow modeling and forecasting in the future. The equation functions a1 and a0 were calculated by the method of least squares. Since, in the selected production regression models, Fdis.>Ftab. (Ftab.= 0.0045), then with a reliability of P = 0.95 the selected econometric models of the dependence of the effective indicator of the gross domestic product per person on the factors of the seasonality indices of outbound and domestic tourists can be considered as adequate initial data, so it is possible to carry out modeling and in the subsequent post-war period of forecasting this indicator. Next, we analyze the correlation coefficients of selected production models of gross domestic product per person. They vary from a weak connection to a close one and indicate that different factors affect the performance indicator differently (Table 2). The coefficients of determination of the investigated and selected production models in the table 2 are also different, and testify to the different

Table 2

Results of data processing to determine the production function of gross domestic product per person, 2015–2021

Impact factor: index of seasonality of outbound tourists					
Production function in general form	**Regression parameters**		**Coefficient of determination "R²"**	**Correlation coefficient "r"**	**Estimated value of Fisher's "F test", "F calculated"**
	a_1	a_0			
$Y = a_1 X + a_0$	-18597,16	120977,78	0,85	0,77	1,02
$Y = a_1 / X + a_0$	37769,05	65842,48	0,83	0,68	0,94
$Y = a_1 \ln X + a_0$	-26839,63	102870,64	0,74	0,80	0,87
$Y = a_1 e^X + a_0$	2590,95	82132,23	0,92	0,93	0,97
$Y = a_1 / \ln X + a_0$	-4162,42	113743,00	0,78	0,22	1,05
$Y = a_1 \sqrt{X} + a_0$	-44838,65	147437,13	0,55	0,58	0,70
$Y = a_1 / \sqrt{X} + a_0$	63859,70	39345,93	0,64	0,59	0,75
$Y = a_1 X^2 + a_0$	-6256,34	108332,99	0,62	0,44	0,84
$Y = a_1 / X^2 + a_0$	26051,51	78625,17	0,63	0,56	0,71
$Y = a_1 X^3 + a_0$	-2718,65	104627,55	0,62	0,51	0,91
$Y = a_1 / X^3 + a_0$	23630,07	82533,90	0,82	0,65	0,89
$Y = \frac{1}{a_1 X + a_0}$	37768,65	65842,08	0,43	0,58	0,54
$Y = a_1 \sqrt[3]{X} + a_0$	-55793,09	120977,78	0,85	0,77	1,02
$Y = a_1 / \sqrt[3]{X} + a_0$	113305,56	65842,48	0,83	0,88	0,94
$Y = a_1^X a_0$	-1957397866,25	132942,78	0,70	-0,84	9,24
$Y = X^{a_1} a_0$	1,11	29734,80	0,65	0,81	7,48
Impact factor: index of seasonality of domestic tourists					
Production function in general form	**Regression parameters**		**Coefficient of determination "R²"**	**Correlation coefficient "r"**	**Estimated value of Fisher's "F test", "F calculated"**
	a_1	a_0			
$Y = a_1 X + a_0$	69418,43	-49717,80	0,36	0,60	2,23
$Y = a_1 / X + a_0$	-277947,42	229853,67	0,34	-0,58	2,02
$Y = a_1 \ln X + a_0$	139660,08	-6789,64	0,35	0,59	2,13
$Y = a_1 / \ln X + a_0$	-63015,80	183221,14	0,30	-0,55	1,73
$Y = a_1 / \ln X + a_0$	8917,68	21390,67	0,37	0,61	2,34
$Y = a_1 \sqrt{X} + a_0$	197189,76	-189297,40	0,85	0,59	2,68
$Y = a_1 / \sqrt{X} + a_0$	-394587,57	369469,53	0,94	-0,58	2,68
$Y = a_1 X^2 + a_0$	17072,70	19924,27	0,92	0,60	2,85

Continuation of table 2

$Y = a_1 / X^2 + a_0$	-273524,00	160073,52	0,92	-0,57	2,48
$Y = a_1 X^3 + a_0$	5542,35	42981,49	0,91	0,61	2,90
$Y = a_1 / X^3 + a_0$	-354860,63	136788,67	0,30	-0,55	1,74
$Y = \frac{1}{a_1 X + a_0}$	-277947,02	229854,07	0,74	-0,58	2,42
$Y = a_1 \sqrt[3]{X} + a_0$	208255,30	-49717,80	0,36	0,60	2,23
$Y = a_1 / \sqrt[3]{X} + a_0$	-833842,27	229853,67	0,34	0,12	2,02
$Y = a_1^X a_0$	-2913041293,13	159663,98	0,75	-0,87	12,03
$Y = X^{a_1} a_0$	2,18	-8011,04	0,83	0,91	20,09

Source: calculated by the author

quality of the models. Next, we determine the best production regressions of gross domestic product per person taking into account the seasonality index of outbound tourists, 2015–2021 — a non-linear function $Y = 2590.95/\ln X + 2132.23$ and gross domestic product per person taking into account index of seasonality of domestic tourists, 2015–2021 using the nonlinear function $Y = X^{2.18}(-8011.04)$. Using the dynamic series of the index of seasonality of outbound and domestic tourists and the effective indicator of gross domestic product per person and significant coefficients of nonlinear functions $Y = 2590.95/\ln X + 82132.23$ and $Y = X^{2.18}(-8011.04)$ for analytical characteristics and comparison, we determine the theoretical level of gross domestic product per person (Table 3).

Graphically, the actual and theoretical values of the gross domestic product per person, taking into account the studied factors and the use of non-linear functions for the last period of the study, are presented in Fig. 1.

Also, in the research, analysis and modeling, it is proposed to follow the dynamics of the total number of tourists served by tour operators and travel agents and by types of tourism over the last studied period.

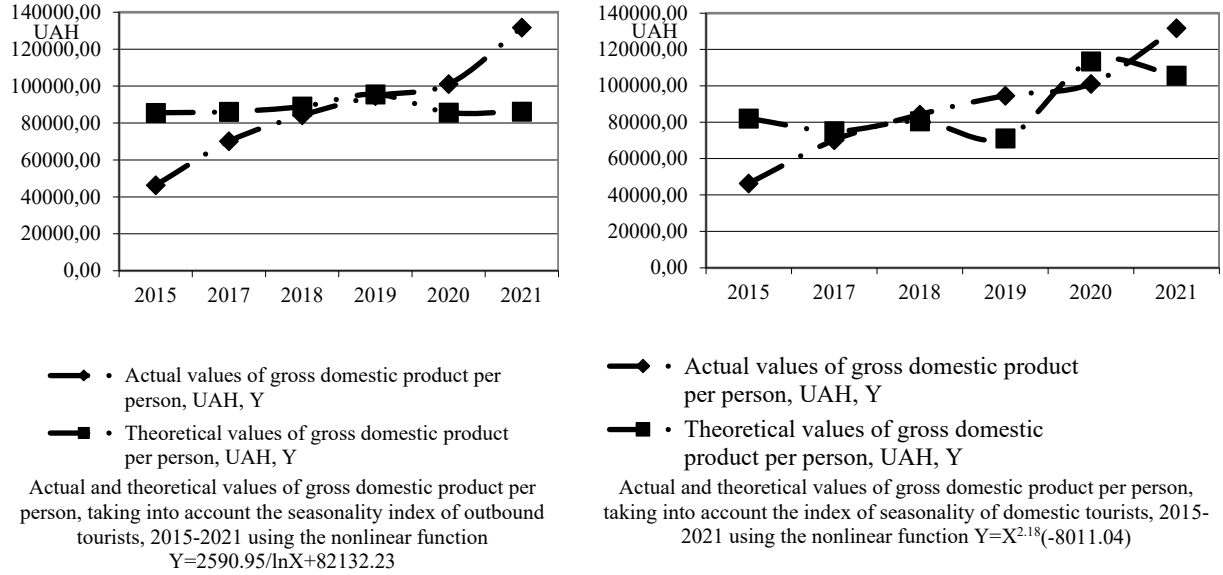
The share of tourists served by tour operators and travel agents by type of tourism was calculated

Table 3

Actual and theoretical values of gross domestic product per person, 2015–2021

Calculation of theoretical values of gross domestic product per person, 2015–2021 using the nonlinear function $Y = 2590.95/\ln X + 82132.23$		
Years	Actual values of gross domestic product per person, UAH., *Y*	Theoretical values of gross domestic product per person, UAH., *Y*
2015	46413,00	85556,42
2017	70170,00	86161,68
2018	84228,00	88981,88
2019	94633,00	95610,80
2020	101138,00	85744,25
2021	131734,00	86278,71
Calculation of theoretical values of gross domestic product per person, 2015–2021 using the nonlinear function $Y = X^{2.18}(-8011.04)$		
Years	Actual values of gross domestic product per person, UAH, *Y*	Theoretical values of gross domestic product per person, UAH., *Y*
2015	46413,00	82118,89
2017	70170,00	75148,06
2018	84228,00	80612,65
2019	94633,00	71230,47
2020	101138,00	113509,33
2021	131734,00	105696,60

Source: calculated by the author



Actual and theoretical values of gross domestic product per person, taking into account the seasonality index of outbound tourists, 2015-2021 using the nonlinear function Y=2590.95/lnX+82132.23

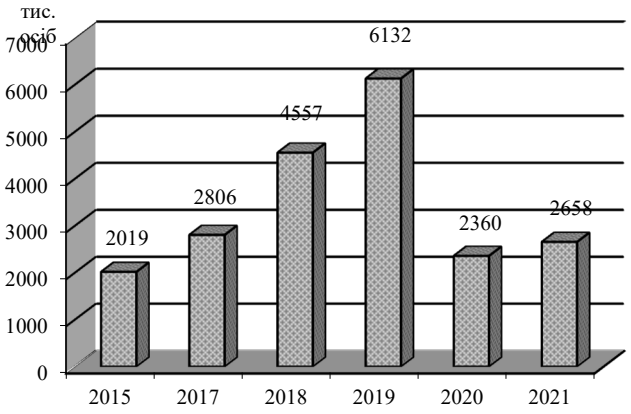
Actual and theoretical values of gross domestic product per person, taking into account the index of seasonality of domestic tourists, 2015-2021 using the nonlinear function $Y=X^{2.18}(-8011.04)$

Figure 1. Actual and theoretical values of gross domestic product per person, taking into account the studied factors and using non-linear functions, 2015–2021

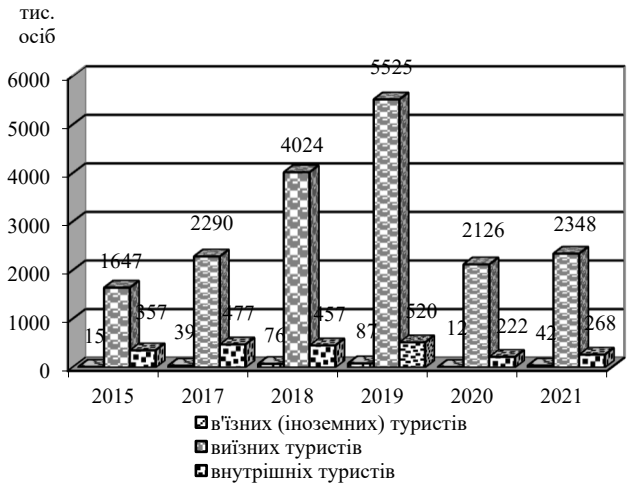
Source: development of the author

and the dynamics of the share of tourists served by tour operators and travel agents by type of tourism was graphically depicted, 2015–2021 (Table 4 and Fig. 3).

So, the researched topic of the interdependence of the seasonality index and the gross domestic product per person using economic and mathematical methods and models proves the ambiguity in the conclusions and descriptions of the resulting modeling. After all, the flow of tourists during the calendar year depends on many factors and tourist preferences, can affect both the overall production of the gross domestic product and other macro indicators of the national economy. In this case, hedging risks and reducing uncertainty in the market of the tourism industry requires obtaining timely, broad and reliable information, both at the level of marketing, financial and economic research. That, in combination with statistical and economic-mathematical modeling tools, will allow the tourism business to determine attractive segments for tourism activities and attracting tourists. Our further research will focus on forecasting trends in the development of the tourism sector and determining its impact on the macroeconomic development of the country.



Dynamics of the number of tourists served by tour operators and travel agents, 2015-2021.



Dynamics of the number of tourists served by tour operators and travel agents, by types of tourism, 2015-2021.

Figure 2. Dynamics of the total number of tourists served by tour operators and travel agents and by types of tourism, 2015–2021

Source: built by the author using the source https://www.ukrstat.gov.ua/

Table 4

Dynamics of the share of tourists served by tour operators and travel agents, by types of tourism, 2015–2021

Years	2015	2017	2018	2019	2020	2021	On average, 2015–2021
Tourists, everything, %	100,00%	100,00%	100,00%	100,00%	100,00%	100,00%	100,00%
share of incoming (foreign) tourists	0,74%	1,39%	1,67%	1,42%	0,51%	1,56%	1,22%
share of outbound tourists	81,58%	81,61%	88,30%	90,10%	90,08%	88,34%	86,67%
share of domestic tourists	17,68%	17,00%	10,03%	8,48%	9,41%	10,09%	12,11%

Source: development of the author

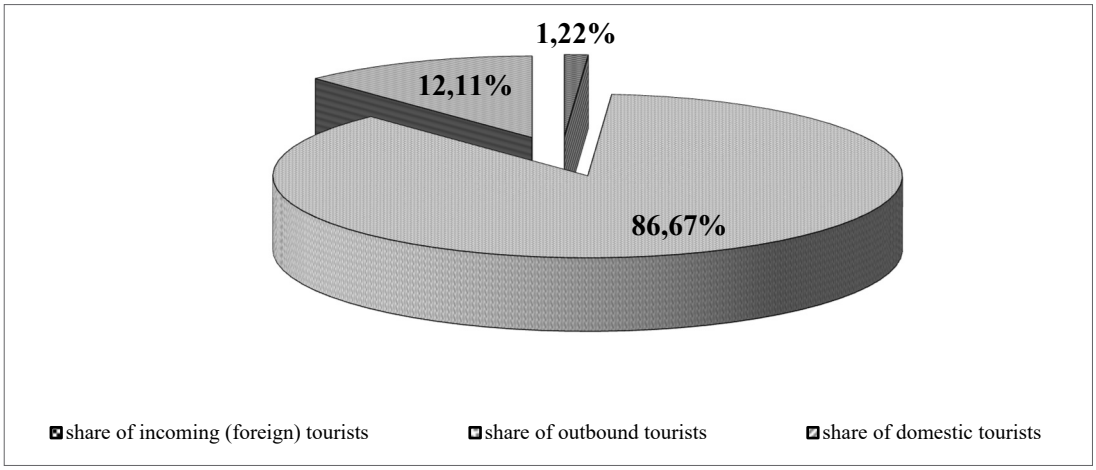


Figure 3. Dynamics of the share of tourists served by tour operators and travel agents, by types of tourism, 2015–2021

Source: built by the author using the source https://www.ukrstat.gov.ua/

4. Conclusions

Gross domestic product and tourism have a deep connection. Tourism is an important component of the economy of many countries, and affects macroeconomic indicators through a variety of financial, social or economic factors. One of the ways to detail the issue of the impact of tourism on macroeconomic indicators is the analysis of direct costs of tourists or tour operators, the dynamics of seasonality of tourist flows, etc. These indicators create a direct economic impact and contribute to an increase or decrease in the socio-economic development of the country. In addition, tourism also stimulates other sectors of the economy such as construction, trade, transport and services. For example, to ensure the growth of the tourism sector, it may be necessary to build new hotels, develop infrastructure, or implement a number of investment projects. In turn, the growth of the socio-economic development of the country can also contribute to the development of tourism, as there is an increase in the income of the population, which can lead to an increase in spending on travel and recreation. However, it is important to consider that tourism can also have a negative impact on some aspects of the economy and society, such as increased environmental pressure, infrastructure overload and cultural erosion. Therefore, it is important to balance the development of tourism taking into account sustainable development, preservation of natural and cultural resources.

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МОДЕЛЮВАННЯ ВЗАЄМОЗВ'ЯЗКУ ЕКОНОМІЧНОГО РОЗВИТКУ КРАЇНИ ТА НАЦІОНАЛЬНОГО ТУРИЗМУ

Анотація. *Туризм посідає важливе місце в соціально-економічному розвитку будь-якої країни та підвищення її конкурентних позицій на світовій арені. Ефективно працюючи туристичні сектори сприяють створенню нових робочих місць, наповнюють бюджети усіх рівнів, привертають інвестиції в інфраструктуру, допомагають зберегти або відновити культурно-історичні пам'ятки, а також стимулюють залучення населення до традиційних мистецтв та інноваційних ремесел. У такому випадку особливе значення має ґрунтовне дослідження особливостей функціонування туристичного сектору економіки, а також визначення його внеску у макроекономічний розвиток країни. Аналіз тенденцій або взаємозв'язків між макроекономічним розвитком країни та туристичними потоками може допомогти краще зрозуміти, яким чином туризм впливає на економіку країни.*

Для вирішення проблематики нашого дослідження нами проаналізовано такі показники як: індекси сезонності виїзних та внутрішніх туристів; валовий внутрішній продукт у розрахунку на одну особу; кількість туристів, обслугованих туроператорами та турагентами тощо. В процесі аналізу нами використовувалися методи моделювання виробних функцій, регресійний та кореляційний аналізи та окремі вбудовані статистичні функції в програмному ресурсі «Statistica».

За результатами моделювання нами отримані чисельні виробничі функції, регресійні рівняння, моделі, які дозволили визначити залежність та вплив туристичних потоків на основний макроекономічний показник країни. Зазначена методика аналізу залежності валового внутрішнього продукту від туристичних потоків є базою для подальшого прогнозування окреслених тенденцій.

Взаємозалежність індексу сезонності та валового внутрішнього продукту у розрахунку на одну особу з використанням економіко-математичних методів та моделей засвідчує неоднозначність у висновках та описах результативного моделювання. Адже, потік туристів протягом календарного року залежить від багатьох чинників та туристичних вподобань, може впливати як на загальне виробництво валового внутрішнього продукту, так і на інші макропоказники національної економіки.

Ключові слова: *туристична діяльність, туристичні потоки, туроператори, турагенти, валовий внутрішній продукт, виробничі функції, індекс сезонності.*

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