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MACROECONOMIC ANALYSIS OF A COUNTRY'S DEVELOPMENT: SECURITY ASPECT

Abstract. *The global economy in the current period of evolutionary development is constantly changing and transforming due to the need to adapt it to the changing conditions of civilisational development. Every country in the world experiences global changes that put on the agenda the issues of ensuring an appropriate level of security in the financial, economic and food sectors. An important issue is the timely monitoring of economic security and forecasting of further social and economic development of the country.*

The panel data for our study consisted of 19 indicators of measuring the macroeconomic security of Ukraine, which we defined as stimulants, nominators and destimulants. The informational basis of forecasting is the reported data of the macroeconomic development of the country. With the usage of methods of statistical modelling, expert judgement, least squares, Fisher's criterion, correlation and regression analysis, the predicted values of macroeconomic security indicators and the level of shadowing of the economy were calculated. For an experimental purpose, it is proposed to compare the results of integral assessments and the predicted values of macroeconomic security of the country in two methods, namely: expert assessment and modified principal component.

The results of estimating the country's macroeconomic development obtained by the modified principal component method are significantly higher than those obtained from expert judgement. In 2013–2017, the difference between these estimates decreases, but the modified principal component estimate method remains higher. In 2018–2020, the estimate obtained by the expert valuation method becomes higher. The forecast for 2023–2024 assumes a stabilisation of the integral estimate. The modified principal component method predicts a certain increase compared to 2020, while the expert valuation method predicts a slight decrease. The results of modelling the further macroeconomic development of the country indicate the need for government managers to focus on the processes of attracting investment and stabilising the labour market, which would significantly increase the country's security.

The proposed logic of macroeconomic analysis of a country's functioning can be used in planning or strategising public policy for social and economic development. Taking into account the changes obtained in the process of such analysis will make it possible to increase the level of security of the country. Determination of forecast values of the level of shadowing of the economy will allow stakeholders to make adaptive managerial decisions in the direction of bringing the economy out of the shadow and stimulating security aspects of the country's development.

Keywords: *security, economic shadowing, labour productivity, wage, balance of payments, consumer price index, savings*

1. Introduction

Macroeconomic analysis of a country's development is an essential tool for ensuring the country's social and economic, financial, product and social security. The timeliness and usability of the security assessment procedure guarantees the effectiveness of management decisions and increase of the country's competitiveness. In addition, the volatility of the external environment and global trends undoubtedly influence the current development of Ukraine. In such case, timely diagnosis and determination of the cause-and-effect relations of changes in macroeconomic trends will enable the adjustment of the state development policy and forecasting of major trends. The level of shadowing of the national economy is of great importance for supporting the security of the country. The above-mentioned problems determine the importance of the study and its relevance in security science.

The aim of the article is to provide a logical macroeconomic analysis of a country's development in the context of a security aspect.

In the scientific findings of Sun *et al.,* [1], it is rightly noted that high-quality development of society and the economy as a whole is possible through a detailed analysis of economic and environmental security. That is why the authors proposed a methodology for determining the level and model of the dynamic development of environmental and economic security of different provinces and regions in the context of sustainable development. The resulting calculations have made it possible to determine the causes of natural resource depletion, which is necessary for the comprehensive, stable and quality social and economic development of individual provinces. The authors have determined the level of ecological and economic security in China, as well as the impact of the territorial location of the region on the ecologisation as a whole.

Su *et al.,* [2] have analysed food security as a necessary component of state economic development. The authors made an interstate comparison of food security in 25 countries for the period 1995–2019. Useful for our study is the system of indicators to assess food security and the inclusion to their group of secondary food security indicators that support food sustainability. The results obtained in the article show that economic policy uncertainty has a negative impact on food security, especially in developed and food-exporting countries. The mentioned modelling allowed the authors to propose a system of factors to increase food security: increasing of political support for grain production, increasing of capital investment, strengthening free trade, etc.

Song *et al.,* [3], investigated the relationship between natural resource assets, economic growth and economic security. The scientists proposed a mechanism of three methods to account for natural resource assets, as well as estimates of China's energy, minerals, water, land, and forests. What is important for our study is the combination of methods that the authors use to assess the linkage.

In their scientific researches Semenov *et al.,* [4], proposed an adaptive model for assessing the dynamics of financing measures for the development and implementation of innovative energy- and resource-saving projects in the agro-food sector. The combination of evaluation indicators and their statistical processing is of particular scientific interest for our study.

An article by Lee *et al.,* [5], focuses on modelling the impact of income on energy security and the economy as a whole. Using six indicators of energy security, the authors investigated their impact on income distribution. The strength of the scientific paper is the broad coverage of the information base of the study, where, using panel data from 68 countries for 2001–2018, the authors obtained an inverted U-shaped impact of energy security on income inequality. The findings have valuable advice for policymakers and academics who deal with the issues of assessing economic, energy or financial security at the macro level.

Tutak and Brodny, [6], using the functioning of the European Union as an example, diagnose the state of energy security in the "Three Seas Initiative" countries and determine how it has changed between 2009 and 2019. Interestingly, the article uses grey relational analysis (GRA) to analyse 17 indicators characterising security in the energy, economic, environmental and social aspects. The indicator weights were defined as the average by the methods: CRITIC, entropy and standard deviation. The results made it possible to segment security levels between the European Union countries, to identify leaders, outsiders and to formulate proposals.

Chi *et al.,* [7], who identified the causes of the energy dependence of Chinese regions, have conducted similar studies. Security was calculated in five segments: politics, economy, law, technology, and geography. Panel data covered the period from 2011 to 2018, and the application of the entropy method allowed for an objective assessment of the security of China and 22 countries in four regions of Northeast, Central, South and Southeast Asia.

The research of Semenov *et al.,* [4], Lee *et al.,* [5], Tutak and Brodny, [6] and Chi *et al.,* [7], is of particular scientific interest in the context of the resource-saving and greening of an industry that the entire global community is striving for.

Li *et al.,* [8], in the context of defining the triple attributes (i.e. equity, efficiency and security), proposed a methodology to assess sustainable water resources usage. Using the Ginny coefficient, method of data coverage analysis and water ecological footprint model, water resources equity, efficiency and environmental security indices were calculated. The resource usage assessment modelling was carried out for 2005–2019 with a diagnosis of 31 provinces and cities of China. The usage of the method of coverage data analysis, which allowed the authors to obtain important results for resource conservation and improvement of the environmental security of the country, is of interest to us.

The scientific views of Blihar *et al.*, [9], are of particular value within the subject matter of our study. Their article outlines a very important issue of our time — strengthening the financial and economic security of the country by developing a strong economic policy of Ukraine. The authors have analysed the financial and economic security of Ukraine and proposed directions for the reorientation of state regulation from the spontaneous development "financialisation mechanism" to the policy of supporting an appropriate level of financial security.

Bezverkhyi *et al.*, [10], proposed a very interesting model for assessing the integrated accounting of business entities. The authors carried out the selection of criteria to build an econometric model for assessing the quality of integrated accounting and analysed the results obtained. The logic of criteria selection and their statistical processing are of scientific interest in the framework of our study.

Important scientific findings have been obtained in the works of other scholars: Prievoznик *et al.*, [11], Conrad *et al.*, [12], Xue *et al.*, [13], Koshkina and Sharamko, [14], Breiding *et al.*, [15], Ereshko and Karanina, [16], Bricker and Bucks, [17], which are useful for our paper. The above works of researchers show an increased interest in the procedure for analysing macroeconomic security assessment. At the same time, there is a need to expand the logic of modelling integral indicators of macroeconomic security assessment and to revise the existing methodologies.

2. Materials and Methods

We propose to determine the macroeconomic security of the country's development using the methods of statistical modelling, expert estimation, least squares, Fisher criterion, correlation and regression analysis and Holt's method. Macroeconomic security is an important component of a country's economic security. Its level is determined by a set of indicators reflecting the balance of macroeconomic reproduction proportions. Let us denote the set of these indicators by X, and individual indicators included in this set by x_i. These indicators are divided into stimulants, whose increase contributes to better macroeconomic security, destimulants, whose increase diminishes macroeconomic security, and nominators, for which deviations in one direction or another from certain optimal values are undesirable. The characteristics selected for the study are shown in Table 1.

In order to make effective management decisions to improve the country's macroeconomic security, it is important to determine the expected future values of these indicators. The information basis for forecasting is statistical data for the retrospective period 2010–2020. Let us define by $x_i(t)$ the value of the indicator xi in t year of the period. These values are shown in Table 2.

Table 1

Macroeconomic security assessment indicators

Indicator	Content of the indicator	Type of the indicator
x_1	The difference between the growth rates of average monthly wages and labour productivity	Nominant, optimal value from −0.5 to 0.5
x_2	Level of the shadow economy as a percentage of GDP	Destimulant
x_3	Current account balance of Ukraine's balance of payments as a percentage of GDP	Nominant, the optimal value is from −1.5 to 1.5
x_4	Unemployment rate, i.e. the ratio of the number of unemployed registered in the state employment service to the number of employable people of working age (in percentage terms)	Destimulant
x_5	The long-term unemployment rate, i.e. the ratio of the number of unemployed for more than 12 months to the total number of unemployed (in percentage terms)	Destimulant
x_6	The difference between Ukraine's GDP growth rate and the growth rates of developing economies	Stimulant
x_7	Consumer price index	Nominant, the optimal value is from 2 to 3
x_8	Ratio of disposable income to GDP (percentage)	Nominant, the optimal value is from 53 to 55
x_9	Propensity of the population to save (in per cent)	Nominant, the optimal value is from 12 to 14
x_{10}	The ratio of wages volume to social benefits volume and other current transfers received, in the total structure of the population's income	Stimulant
x_{11}	Ratio of GDP per capita in Ukraine to the average value in the EU (in per cent)	Stimulant
x_{12}	Employment in the informal sector of the economy, as a percentage of the total number of employed people	Destimulant

Source: combination of indicators adapted by the authors from https://zakon.rada.gov.ua/rada/show/v1277731-13

Table 2

Values of macroeconomic security indicators of Ukraine

Indicator	Years										
	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
x_1	6,5	3,6	14,4	8,5	-6,4	-19,4	5,5	15,9	10,4	7,9	7,4
x_2	36	31,8	30,3	30,4	35,7	35,1	32,6	31,8	29	28	30
x_3	-2,1	-6	-7,9	-8,7	-3,4	5,5	-2	-3,1	-4,9	-2,7	4
x_4	8,2	8	7,6	7,3	9,3	9,1	9,3	9,5	8,8	8,2	9,5
x_5	33,9	28,4	28	27,3	20,1	20,4	25,3	26,7	21,6	13,1	21,2
x_6	-3,3	-0,9	-5,1	-5,1	-11,5	-14,1	-2,2	-2,3	-1,1	-0,4	-1,8
x_7	9,1	4,6	-0,2	0,5	24,9	43,3	12,4	13,7	9,8	4,1	5
x_8	78,6	76,1	81,8	83	72,6	68,5	66,3	67,4	69,4	73,1	73,1
x_9	19,1	12,4	12,8	9,6	2,7	2,3	0,8	1,5	1,3	-0,4	-0,6
x_{10}	1,06	1,13	1,12	1,08	1,09	1,08	1,28	1,36	1,4	1,48	1,36
x_{11}	8,78	9,8	11,95	11,34	8,49	6,6	6,8	7,8	8,5	10,5	11
x_{12}	22,9	23,1	22,9	23,6	25,1	26,2	24,3	22,9	21,6	20,9	20,3

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

The adaptive Holt model is used to predict the dynamics of these indicators. A feature of this model is that it takes into account the presence of a trend. The model is applied when there is an upward or downward trend in the dynamics of its values. When examining the values of the following indicators xi during the retrospective period, revealed trends in the dynamics of the indicators x_2, x_4, x_5, x_8, x_{10}, x_{11}, x_{12}. Therefore, the Holt model can be used to determine the expected future values of these indicators. This model uses two coefficients, the row-smoothing coefficient α and the trend-smoothing coefficient β. The values of these coefficients are selected empirically. In our study of the dynamics of the selected indicators, a value of $\alpha = 0{,}9$ and $\beta = 0{,}05$, was adopted, which allowed us to obtain a high estimate of forecast accuracy.

When forecasting xi, using the Holt model, for each value of t from the retrospective period, the elements $g_i(t)$ of the exponentially-smoothed series and the trend value $r_i(t)$ are determined using the recurrent formulas

$$g_i(t) = \alpha x_i(t) + (1-\alpha)(g_i(t-1) + r_i(t-1))$$
$$r_i(t) = \beta(g_i(t) - g_i(t-1)) + (1-\beta) r_i(t-1)$$

For the first period, consider that

$$g_i(1) = x_i(1),\ r_i(1) = 0.$$

After determining the values of $g_i(t)$ and $r_i(t)$ for all years of the retrospective period, to make a forecast of x_i indicators use the formula

$$x_i(T+j) = g_i(T) + j r_i(T)$$

where T is the number of years in the retrospective period.

To assess the accuracy of the prediction, determine for each value of t from $t = 2$ to $t = T$ the values

$$q_i(t) = g_i(t) + r_i(t),\ \Delta_i(t) = x_i(t) - q_i(t)$$

та

$$\delta_i(t) = \frac{\Delta_i^2(t)}{x_i^2}.$$

The prediction accuracy is determined by the equality

$$\nu_i = 1 - \frac{\sum_{t=2}^{T} \delta_i(t)}{T-1}.$$

The definition of the projected values for indicator x_2 is shown in Table 3.

Similarly, forecast values are determined for the indicators x_4, x_5, x_8, x_{10}, x_{11} and x_{12}. The forecast results are presented in the Table 4.

For the other macroeconomic security indicators, Holt's model does not apply, as no trends in their dynamics have been identified. In some years of the retrospective period, the value of these indicators differs significantly from their level in other years. Such years are 2014 and 2015 for x1, x6 and x7, 2015 for x_3, and 2010, 2011, 2012 and 2013 for x9.

To forecast these indicators we use a multiple linear regression equation $x_i(t) = a_{i0} + a_{i1}t + a_{i2}w_i(t)$, where w_i, is an artificial variable equal to 1 for those t values that correspond to the years in which the variable x_i takes significantly different values and equal to 0 for other t values. The values of the variables w_i for the indicators x_1, x_3, x_6, x_7 and x_9 are given in Table 5.

The coefficients a_{i0}, a_{i1} and a_{i2} of the equations of multiple linear regression are determined by the least squares method. To check the adequacy of the obtained equations, we use Fisher's criterion. Determine the coefficient of determination R^2 by the formula

$$R^2 = 1 - \frac{\sum_{t=1}^{T} \left(x_i - a_{i0} - a_{i1}t - a_{i2}w_i(t)\right)^2}{\sum_{t=1}^{T} \left(x_i(t) - \bar{x}_i\right)^2}$$

Table 3

Determination of forecast values of the level of economic shadowing

Year	t	$x_2(t)$	$g_2(t)$	$r_2(t)$	j	$x_2(T+j)$	$q_2(t)$	$\Delta_2(t)$	$\delta_2(t)$	v_2
2010	1	36	36	0,000			36			99,32%
2011	2	31,8	32,22	-0,189			36	-4,2	0,017	
2012	3	30,3	30,47	-0,267			32,031	-1,731	0,003	
2013	4	30,4	30,38	-0,258			30,206	0,194	0,000	
2014	5	35,7	35,14	-0,007			30,122	5,578	0,024	
2015	6	35,1	35,10	-0,009			35,135	-0,035	0,000	
2016	7	32,6	32,85	-0,121			35,095	-2,495	0,006	
2017	8	31,8	31,89	-0,163			32,728	-0,928	0,001	
2018	9	29	29,27	-0,286			31,730	-2,730	0,009	
2019	10	28	28,10	-0,330			28,987	-0,987	0,001	
2020	11	30	29,78	-0,230			27,769	2,231	0,006	
2021					1	32,728				
2022					2	32,607				
2023					3	32,486				
2024					4	32,365				

Source: Calculated by the authors

where $\bar{x}_i$ is the mean value of the indicator xi during the retrospective period. Then we determine the actual value of Fisher's criterion by the following equation

$$F = \frac{R^2}{1-R^2}\frac{T-3}{2}.$$

Let us compare the obtained value with the table value of the Fisher criterion, which corresponds to probability 0.05 and degrees of freedom $k_1 = 2$, $k_2 = T - 3 - 8$. If the actual value is larger than the table value, the equation is adequate and can be used to predict the value of the indicator x_i. The values of

Table 4

Projected values of macroeconomic security indicators obtained by using Holt's model

Indicator	Content of the indicator	Forecast for 2023	Forecast for 2024	Accuracy of the forecast
x_2	Level of the shadow economy as a percentage of GDP	32,5	32,4	99,32%
x_4	Unemployment rate (in per cent)	9,4	9,5	99,16%
x_5	Long-term unemployment rate (in per cent)	23,9	23,3	91,74%
x_8	Ratio of population disposable income to GDP (in per cent)	64,8	64,2	99,61%
x_{10}	Ratio of the volume of wages to the volume of social benefits and other current transfers received	1,3	1,3	99,54%
x_{11}	Ratio of GDP per capita in Ukraine to the average value in the EU (in per cent)	6,5	6,4	96,42%
x_{12}	Employment in the informal sector of the economy as a percentage to the total employed population	24,7	24,8	99,75%

Source: calculated by the authors

Table 5

Value of artificial variables w_i

Variables	Years										
	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
w_1	0	0	0	0	1	1	0	0	0	0	0
w_3	0	0	0	0		1	0	0	0	0	0
w_6	0	0	0	0	1	1	0	0	0	0	0
w_7	0	0	0	0	1	1	0	0	0	0	0
w_9	1	1	1	1	0	0	0	0	0	0	0

Source: calculated by the authors

Table 6

Parameters of multiple linear regression equations for macroeconomic security indicators

Indicator	a_{i0}	a_{i1}	a_{i2}	R^2	F
x_1	8,08436	0,13347	-21,71844	0,78552	14,64949
x_3	-7,24182	0,59364	9,18000	0,60039	6,00981
x_6	-3,92291	0,23829	-10,18771	0,89659	34,68174
x_7	3,82123	0,44744	27,81788	0,78591	14,68378
x_9	8,07965	-0,87424	7,58095	0,92758	51,23270

Source: calculated by the authors

Table 7

Projected values of macroeconomic security indicators, obtained from multiple linear regression equations

Indicator	Content of the indicator	Forecast for 2023	Forecast for 2024
x_1	The difference between the growth rates of average monthly wages and labour productivity	10,0	10,1
x_3	Current account balance of Ukraine's balance of payments as a percentage of GDP	1,1	1,7
x_6	The difference between Ukraine's GDP growth rate and the growth rates of developing economies	-0,6	-0,3
x_7	Consumer price index	10,1	10,5
x_9	Population's propensity to save (in per cent)	-4,2	-5,0

Source: calculated by the authors

regression coefficients, coefficients of determination and actual values of Fisher's criterion for indicators x_1, x_3, x_6, x_7 and x_9 are given in Table 6.

Since the tabulated value of the Fisher criterion F $F(0,05; 2; 8) = 4,45897$, the regression equation for all indicators is adequate. To determine the forecast values of these indicators we substitute the values $t = 14$ and $t = 15$, corresponding to 2023 and 2024, into the corresponding regression equations, and we take the value of artificial variables to be equal to 0. The resulting forecasting results are shown in Table 7.

3. Results and Discussion

The methodological recommendations for calculating the level of economic security of Ukraine, approved by the order of the Ministry of Economic Development and Trade of Ukraine № 1277 dated 29.10.2013, characteristic values for the indicators of the components of economic security of Ukraine were provided, which divide the set of their values into five areas: critical, dangerous, unsatisfactory, satisfactory and optimal. These areas for the indicators of the characteristics of macroeconomic security are shown in Table 8.

If the value of some indicator is not included in any of the listed areas, the value is considered to correspond to an absolutely dangerous level for which the safety level is 0.

By analysing the dynamics of the macroeconomic security indicators and the forecasts developed, the following conclusions can be drawn regarding these characteristics.

1. The difference between the growth rate of average monthly wages and labour productivity during the retrospective period reached an absolutely dangerous level in 2015 (exceeding the lower limit of acceptable values) and in 2012 and 2017 (exceeding the upper limit of acceptable values). In 2020, this indicator was in the critical area. For 2023–2024, it is projected to increase, which has a negative impact on macroeconomic security as the indicator moves away from the optimal area.

2. The level of shadowing of the economy was at an absolutely dangerous level by 2017. The situation improved slightly in 2019, although the indicator was in a critical area. The forecast assumes an increase of the shadowing level to 32.5%, which means a move to an absolutely dangerous level.

3. Ukraine's current account balance as a percentage of GDP has been in a satisfactory range during the retrospective period. The forecast assumes that it will increase and move into the optimal range.

4. The unemployment rate between 2014 and 2017 exceeded 9%, which is an absolutely dangerous level. The situation improved slightly in 2018–2019, although the value of this indicator remained critical. The forecast assumes an increase in the unemployment rate to 9.5%.

5. The long-term unemployment rate has been decreasing since 2014 and has been in the area of satisfactory values. In 2019, this indicator has moved to an optimal level. The forecast assumes an increase of this indicator to 23.3%, which means a transition to a satisfactory level.

Table 8

Areas of values of macroeconomic security indicators

Indicator	Value areas				
	critical	dangerous	unsatisfactory	satisfactory	optimal
x_1	[−15;-10)[8;12]	[−10;-6)[5;8)	[−6;-3)[2;5)	[−3;-0,5)(0,5;2)	[−0,5;0,5]
x_2	[25;30)	[22; 25)	[18; 22)	[13; 18]	< 13
x_3	[−7;-5)[7;10]	[−5;-4)[5;7)	[−4;-3)[3;5)	[−3;-1,5)(1,5;3)	[−1,5;1,5]
x_4	[8;9)	[7; 8)	[6; 7)	[5; 6]	< 5
x_5	[40;50)	[35; 40)	[30; 35)	[20; 30]	< 20
x_6	[−2;-1,5)	[−1,5; −1)	[−1; 1)	[1; 2]	> 2
x_7	[−2;-1)[8;12]	[−1;-0,5)[5;8)	[−0,5;1)[4;5)	[1;2)(3;4)	[2;3]
x_8	[40;43)[63;65]	[43;45)[60;63)	[45;50)[58;60)	[50;53)(55;58)	[53;55]
x_9	[3;5)[20;22]	[5;8)[18;20)	[8;10)[16;18)	[10;12)(14;16)	[12;14]
x_{10}	[1; 1,1)	[1,1; 1,2)	[1,2; 1,4)	[1,4; 1,6]	> 1,6
x_{11}	[10; 25)	[25; 50)	[50; 70)	[70; 90]	> 90
x_{12}	[20;25)	[15; 20)	[10; 15)	[5; 10]	< 5

Source: compiled by the authors using https://zakon.rada.gov.ua/rada/show/v1277731-13

6. The difference between Ukraine's GDP growth rate and the growth rate of developing economies was at an absolutely dangerous level between 2012 and 2017. In 2018–2019, this indicator is increasing and moving to an unsatisfactory level. The indicator is projected to rise to −0.35 percentage points by 2024, but remains in the unsatisfactory range.

7. The consumer price index was in an area of absolute danger between 2014 and 2017. From 2019 this index decreases and reaches 4.9% in 2020. The forecast for 2023–2024 assumes an increase of this index to 10.6%, which is included in the area of critical values.

8. The ratio of population disposable income to GDP has exceeded the maximum permissible level of 65% throughout the retrospective period. The forecast foresees a reduction to 64.2% by 2024.

9. The propensity of the population to save has been decreasing over the retrospective period and has fallen below the minimum value of 3% since 2015. It is forecasted that this indicator will continue to decrease and will reach a value of −5% in 2024.

10. The ratio of volumes of wages to social benefits and other current transfers received reached a satisfactory value of 1.47 in 2019. It is projected to decrease to 1.3 in 2024.

11. The ratio of GDP per person in Ukraine to the EU average is projected to fall from 10.9% in 2019 to 6.4% in 2024, which is below the minimum allowable value.

12. Employment in the informal economy has exceeded the maximum allowable value of 20% throughout the retrospective period. For 2023–2024, this indicator is projected to rise to 24.8%.

Let us define an integral assessment of the country's macroeconomic security that combines all the indicators x_i. For this purpose, it is necessary to normalise the initial indicators, as a result of which the obtained normalised values $y_i(t)$ will belong to the same interval.

For the stimulant-indicators x_i, we denote the lower boundaries of the areas of critical, dangerous, unsatisfactory, satisfactory and optimal values by x_{i1}^+, x_{i2}^+, x_{i3}^+, x_{i4}^+, x_{i5}^+ respectively. Similarly, for destimulant-indicators of x_i we denote the upper boundaries of the areas of critical, dangerous, unsatisfactory, satisfactory and optimal values, by x_{i1}^-, x_{i2}^-, x_{i3}^-, x_{i4}^-, x_{i5}^- respectively. For stimulants, normalisation is carried out according to the formula

$$y_i(t) = \begin{cases} 0,2e^{(x_i(t)-x_{i1}^+)} & if\ x_i(t) < 0 \text{ i } x_i(t) < x_{i1}^+ \\ 0,2\dfrac{x_i(t)x_i(t)}{x_{i1}^+} & if\ 0 \le x_i(t) < x_{i1}^+ \\ 0,2k + 0,2\dfrac{x_i(t) - x_{ik}^+}{x_{i(k+1)}^+ - x_{ik}^+} & if\ x_{ik}^+ \le x_i(t) < x_{i(k+1)}^+ \text{ i } k < 5 \\ 1 & if\ x_i(t) \ge x_{i5}^+ \end{cases}$$

For destimulants, normalisation is carried out using the formula

$$y_i(t) = \begin{cases} 0,2\dfrac{x_{i1}^-}{x_i(t)} & if\ x_i(t) \ge x_{i1}^- \\ 0,2k + 0,2\dfrac{x_{ik}^- - x_i(t)}{x_{ik}^- - x_{i(k+1)}^-} & if\ x_{i(k+1)}^- \le x_i(t) < x_{ik}^- \text{ i } k < 5 \\ 1 & if\ x_i(t) < x_{i5}^- \end{cases}$$

Nominators combine the characteristics of stimulators and destimulators. Before reaching the optimal value, the growth of the following indicators has a positive impact on macroeconomic security, and after going beyond the optimal value, it has a negative impact. Consequently, if the nominator value is less than the optimal value, normalisation

Table 9

Normalised values of the country's macroeconomic security indicators

Indicator	Years										
	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
y_1	0,500	0,693	0,167	0,375	0,573	0,010	0,567	0,151	0,280	0,407	0,440
y_2	0,167	0,189	0,198	0,197	0,168	0,171	0,184	0,189	0,240	0,280	0,200
y_3	0,920	0,300	0,081	0,037	0,720	0,550	0,933	0,780	0,420	0,840	0,700
y_4	0,360	0,400	0,480	0,540	0,194	0,198	0,194	0,189	0,240	0,360	0,189
y_5	0,644	0,832	0,840	0,854	0,998	0,992	0,894	0,866	0,968	1,000	0,976
y_6	0,055	0,610	0,009	0,009	0,000	0,000	0,164	0,148	0,560	0,660	0,280
y_7	0,345	0,680	0,707	0,733	0,096	0,055	0,194	0,175	0,289	0,780	0,600
y_8	0,165	0,171	0,159	0,157	0,179	0,190	0,196	0,193	0,187	0,178	0,178
y_9	0,490	1,000	1,000	0,707	0,180	0,153	0,053	0,100	0,087	0,064	0,031
y_{10}	0,320	0,460	0,440	0,360	0,380	0,360	0,680	0,760	0,800	0,880	0,760
y_{11}	0,176	0,196	0,226	0,218	0,170	0,132	0,136	0,156	0,170	0,207	0,213
y_{12}	0,284	0,276	0,284	0,256	0,196	0,191	0,228	0,284	0,336	0,364	0,388

Source: calculated by the authors

is carried out as for stimulants, and if it is more than optimal value, as for destimulants.

The normalised values of $y_i(t)$ are shown in Table 9.

The Integral assessment of $W(t)$ of the macroeconomic security is obtained from the following equation

$$W(t) = \sum_{i=1}^{12} \gamma_i y_i(t),$$

where γ_i are the weighting coefficients of the indicators. These coefficients can be determined on the basis of expert judgement or the modified principal component method.

The coefficients determined by the expert assessment method are given in the methodological recommendations for calculating the level of economic security of Ukraine. This method allows the usage of the knowledge and experience of experts in the field of macroeconomics, but it also has some drawbacks, one of which is that in determining the weighting coefficients the existing correlations between the various indicators of macroeconomic security are not taken into account. The study of the dynamics of these indicators over a retrospective period showed that there are significant correlations between them. Thus, the correlation coefficients between the indicators x6 (difference in the growth rates of GDP of Ukraine and developing countries) and x1 (difference in the growth rates of average monthly wages and labour productivity), x5 (long-term unemployment rate) and x9 (propensity of population to save), x11 (ratio of GDP per person in Ukraine to average value in EU countries) and x8 (ratio of disposable income to GDP) exceeds 0.8.

The modified principal component method allows us to determine the weighting coefficients of the indicators in the integral assessment by taking into account the correlation between them. In applying this method, the weighting coefficients are taken to be proportional to the squares of the component of the eigenvector of the covariance matrix of the normalized indicators y_i, which corresponds to the maximum eigenvalue of this matrix.

The weighting coefficients of indicators in the integrated assessment of the country's macroeconomic security, determined by expert assessment and the modified principal component method, are shown in Table 10.

To predict the values of the integral assessment of the country's macroeconomic security for 2023 and 2024, let us determine the projected normalised values of $y_i(t)$ of y_i indicators at $t = 12$ and $t = 13$, corresponding to these years. Suitable values are given in Table 11.

The expected values of the integral assessment in 2023 and 2024 are determined from equality

$$W(t) = \sum_{i=1}^{12} \gamma_i y_i(t)$$

at $t = 12$ and $t = 13$. The dynamics of the integral assessment of the country's macroeconomic security in 2010–2020 and the forecast of this assessment for 2023–2024 are shown in Table 12.

The values of the integral assessments of the macroeconomic security of the country in 2010–2020 and the projected values for 2023–2024 obtained by using expert evaluation and modified principal component methods are shown in Figure 1.

The results shown in Figure 1 show slight deviations — the integral assessments of the macroeconomic security of the country in 2010–2020 and the projected values for 2023–2024, based on the methods of expert evaluation and the modified principal component.

4. Conclusions

In 2010–2012, the integral assessment of the country's macroeconomic security obtained by the modified principal component method is significantly higher than that obtained by expert judgement. In 2013–2017, the difference between these estimates

Table 10

Weighting coefficients of indicators in the integral assessment of a country's macroeconomic security

Indicators	Weighting coefficients determined by the expert assessment method	Weighting coefficients determined by the modified principal component method
The difference between the growth rates of average monthly wages and labour productivity	0,0828000	0,0015210
Level of the shadow economy as a percentage of GDP	0,0950000	0,0000023
Current account balance of Ukraine's balance of payments as a percentage of GDP	0,0914000	0,3278708
Unemployment level	0,0914000	0,0406023
Long-term unemployment level	0,0894000	0,0053876
The difference between Ukraine's GDP growth rate and the growth rates of developing economies	0,0717000	0,0750212
Consumer price index	0,0854000	0,0707560
Ratio of population disposable income to GDP	0,0837000	0,0014823
The propensity of the population to save	0,0759000	0,4212010
The ratio of the volumes of wages to the volumes of social benefits and other current transfers received in the total structure of the population's income	0,0798000	0,0530842
Ratio of GDP per capita in Ukraine to the EU average	0,0711000	0,0026729
Population employment in the informal sector of the economy as a percentage of the total employed population	0,0824000	0,0004368

Source: calculated by the authors

decreases, but the modified principal component estimate remains higher. In 2018–2020, the estimate obtained by the expert valuation method becomes higher. The forecast for 2023–2024 assumes a stabilisation of the integral estimate. The modified principal component method predicts a certain increase compared to 2020, while the expert assessment method predicts a slight decrease. The difference between the estimates obtained by different methods can be explained by the fact that when calculating the modified principal component method, due to the identified correlation between the indicators, the weighting coefficients of the indicators differ significantly, while the expert assessment method assumes a small difference between these coefficients. The proposed logic of assessment and forecasting of the country's macroeconomic security

Table 11

Normalised y_i indicators values

Indicator	Year 2023	Year 2024
y_1	0,302	0,296
y_2	0,185	0,185
y_3	1,000	0,978
y_4	0,191	0,189
y_5	0,926	0,933
y_6	0,641	0,665
y_7	0,296	0,273
y_8	0,222	0,279
y_9	0,001	0,000
y_{10}	0,689	0,698
y_{11}	0,129	0,127
y_{12}	0,212	0,210

Source: calculated by the authors

Table 12

Evolution of the integral assessment of the country's macroeconomic security with a forecast for 2023–2024

Years	Integral assessment by the method of expert evaluation	Integral assessment using the modified principal component method
2010	0,37763	0,57320
2011	0,47909	0,66053
2012	0,38379	0,54713
2013	0,37417	0,40933
2014	0,33159	0,35379
2015	0,26019	0,28205
2016	0,37878	0,40484
2017	0,34091	0,37513
2018	0,38352	0,29538
2019	0,50797	0,47555
2020	0,42032	0,36096
2023 forecast	0,40225	0,44721
2024 forecast	0,40371	0,44771

Source: calculated by the authors

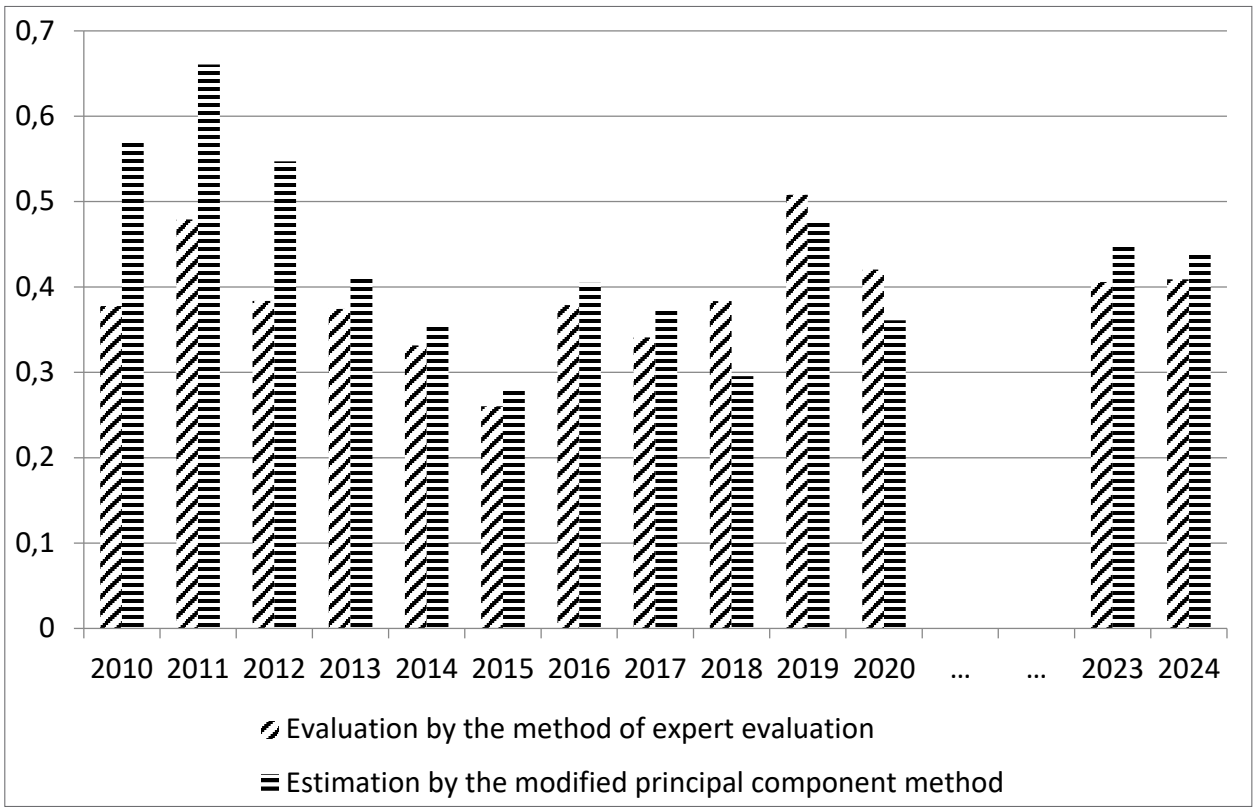

Figure 1. Integral estimates of the macroeconomic security of the country in 2010–2020 and projected values for 2023–2024

Source: calculated by the authors

assessment will be useful to managers of all levels, as well as Ukraine's foreign partners. The purpose of our further research will be to attract more methods and indicators to assess the macroeconomic security of the country, and to form proposals to maintain its proper level.

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МАКРОЕКОНОМІЧНИЙ АНАЛІЗ РОЗВИТКУ КРАЇНИ: БЕЗПЕКОВИЙ АСПЕКТ

Анотація. *Глобальна економіка у сучасний період еволюційного розвитку знаходиться у постійній трансформації та зміні, що обумовлено необхідністю її пристосування до мінливих умов цивілізаційного розвитку. Кожна країна світу відчуває на собі глобальні зміни, що ставить на порядок денний питання забезпечення належного рівня безпеки у фінансовому, економічному, продовольчому секторах. Надважливим питанням є проведення вчасного моніторингу економічної безпеки та формування прогнозу подальшого соціально-економічного розвитку країни.*

Панельними даними в межах нашого дослідження слугували 19 показників вимірювання макроекономічної безпеки України, які визначалися нами як стимулятори, номінатори та дестимулятори. Інформаційною основою прогнозування є звітні данні макроекономічного розвитку країни. З використанням методів статистичного моделювання, експертного оцінювання, найменших квадратів, критерію Фішера, кореляційно-регресійного аналізу розраховані прогнозовані значення показників макроекономічної безпеки та рівень тінізації економіки. З експериментальною метою результати інтегральних оцінок та прогнозовані значення макроекономічної безпеки країни запропоновано порівнювати у два методи, а саме: експертного оцінювання та модифікованої головної компоненти.

Отримані результати оцінки макроекономічного розвитку країни, що одержані методом модифікованої головної компоненти, істотно перевищили оцінку, одержану за допомогою експертного оцінювання. В 2013–2017 роках різниця між цими оцінками зменшилася, але оцінка, одержана за допомогою методу модифікованої головної компоненти, залишається вищою. В 2018–2020 роках вищою стала оцінка, одержана методом експертного оцінювання. Прогноз на 2023–2024 роки передбачає стабілізацію інтегральної оцінки. Метод модифікованої головної компоненти прогнозує певне її зростання порівняно із 2020 роком, а метод експертного оцінювання — незначне зменшення. Результати моделювання подальшого макроекономічного розвитку країни засвідчують, на необхідності зосередження державних управлінців на процесах залучення інвестицій та стабілізації ринку праці, що значно підвищить безпеку країни.

Запропоновану логіку макроекономічного аналізу функціонування країни можливо використовувати при плануванні або стратегуванні державної політики соціально-економічного розвитку. Урахування змін, які будуть отримані в процесі такого аналізу, дозволять підвищити рівень безпеки країни. Визначення прогнозних значень рівня тінізації економіки дозволить зацікавленим стейкхолдерам приймати адаптивні управлінські рішення в напрямку детінізації та стимулювання безпекових аспектів розвитку країни.

Ключові слова: *безпека, тінізація економіки, продуктивність праці, заробітна плата, платіжний баланс, індекс споживчих цін, заощадження.*