Scenario modeling of the critical macroeconomic and sustainable development indicators of Ukraine

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Abstract. The assessment of the state of macroeconomic security as a crucial component of economic security in the context of sustainable development and the forecasting of key indicators are becoming more critical in light of the complicated circumstances that the functioning of the Ukrainian economy is currently experiencing as a result of the full-scale Russian invasion. Therefore, this study aims to build a relevant system dynamic model for assessing and forecasting the level of macroeconomic security in the medium term. A system of dynamic models of three key indicators (GDP growth rate, consumer price index, and unemployment rate) was built based on Romer's model of economic growth with the author's modifications, a kinetic model of the price level, and an author's model of the dynamics of population groups. The model's average error equals 3.25%, the maximum one is 10.927% for the inactive population in 2018. A potential forecast was made, primary and alternative scenario forecasts were developed, and the mathematical expectation of key indicators according to the scenarios was calculated. Meanwhile, none of the developed forecasts characterized the state of the level of macroeconomic security precisely as optimal, which led to the conclusion that there is an urgent need to implement a system of measures to increase macroeconomic security.

1 Introduction

In 2015, Ukraine joined global efforts to achieve the Sustainable Development Goals (SDGs) within the framework of the UN global action plan "Transforming our world: the 2030 Agenda for Sustainable Development" [1]. This integrated action plan is built based on the harmonization of economic, environmental, and social-institutional dimensions of development. It should be noted that two goals out of 17 highlight the importance of economic development, namely: Goal 1, "End poverty in all its forms everywhere," and Goal 8, "Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all" [1].

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In addition, other aspects of sustainable development can only be implemented with available resources. Thus, the indicators characterizing the specified goals form indices of economic development and economic security in the context of sustainable development [2]. Also, economic security, as a component of national security, plays a key role in ensuring economic development, implementing an effective social policy, ensuring the proper standard of living of the population, maintaining the necessary level of resilience of the country's economic system to various external influences, and forming competitiveness in the conditions of international interaction and globalization. As an essential component of economic security, macroeconomic security covers all key areas of the country's development and functioning and primarily signals certain negative phenomena.

Problems with the internal development of Ukraine's economy, active participation in the international trade system, and several adverse external influences pose a significant threat to economic security in general and macroeconomic security in particular. Thus, the economic conditions of the last decade are difficult to classify as those that do not threaten macroeconomic security. The war in the East of Ukraine in 2014 started a series of unfavorable events; the national economy needed many years to restore and replace the lost share of the metallurgical sector and stabilize the inflation level. The following security challenge for the national economy was the financial and economic crisis caused by the spread of the COVID-19 pandemic, which caused a new drop in GDP and an increase in unemployment in 2020. Furthermore, when the situation at the macroeconomic level stabilized, the country faced a full-scale invasion of the Russian Federation into Ukraine, so the year 2022 is characterized by an unprecedented drop in GDP, negative migration processes, a decrease in employment, and an increase in inflation.

In order to respond promptly to security threats, it is necessary to carry out constant monitoring and forecasting of the assessment of the level of macroeconomic security as a complex system. The issues of modeling both indicators and the level of macroeconomic security must also be fully disclosed in the scientific literature if the various theoretical basis for determining the level of security is duly addressed.

Therefore, the study aims to review and generalize the scientific and methodological provisions of modeling and build a system model of assessment relevant to today's conditions and forecast its level in the medium-term perspective.

2 Methods

During the research, the authors used various methods, namely methods of mathematical and regression analysis, economic-mathematical modeling (models of system dynamics), mathematical programming, scenario forecasting, and economic and statistical analysis methods.

Since in the context of modeling economic and macroeconomic security indicators, it is usually suggested to use regression models [3, 4] or extrapolation methods [5], which have apparent drawbacks, at this stage, the authors faced the task of building a specific dynamic model for calculating macroeconomic security indicators. For this purpose, it was necessary to consider the key indicators and their models separately, after which a system model should be formed. Therefore, for the indicator of GDP growth, it is advisable to use one of the economic growth models studied by Solow [6] and Swan [7], Lucas [8], and Romer [9]. Unfortunately, the modeling of inflation and the level of unemployment is not such an everyday topic among scientists: for model inflation, it is suggested to use various modifications of the Phillips curve [10] or the Fisher equation [11, 12]; regarding the modeling of the level of unemployment, in the scientific literature, only the author's models are offered [13, 14].

After modeling the indicators, it is necessary to carry out their normalization and calculation of the integral subindex of macroeconomic security; for this, it is worth using the methods proposed in the Methodological recommendations for assessing Ukraine's economic security level [15]. The statistical data used in this study was taken from the reports of the State Statistics Service of Ukraine [16], the National Bank of Ukraine [17], the World Bank [18], and the International Monetary Fund [19].

3 Results

Following the Methodological recommendations for assessing Ukraine's economic security level [15], macroeconomic security is defined as "the state of the economy in which the balance of macroeconomic reproductive proportions is achieved." Reproductive proportions mean the ratio of elements, sides, and stages of the reproduction process, which include production, distribution, exchange, and consumption. When analyzing macroeconomic security, the following elements are often distinguished: economic independence, sustainability and stability of the national economy, and the ability for self-development and progress.

The basis for assessing the country's macroeconomic security level is the security criteria – signs based on which the state of the economy, its stability, and security are assessed. Quantitative expression of criteria is indicators or indicators characterizing the form of a specific security component; the list of such indicators is variable. Methodological recommendations for assessing the level of economic security of Ukraine [15], in which twelve indicators are identified, can be considered authoritative in the matter of determining the list of these indicators; The Presidential Decree "On the Strategy of Economic Security of Ukraine for the Period Until 2025" [20], in which a slightly narrower list of indicators is included in the indicators of macroeconomic security, namely seven indicators; Analytical report Forecasting indicators, threshold values and the level of economic security of Ukraine in the medium-term perspective [21], in which the authors highlight their list of 7 indicators of macroeconomic security, different from previous methods. On the other hand, macroeconomic indicators describe a range of targets within the scope of sustainable development goals. For example, the rate of GDP growth provides a measurement of the Target 8.1 "Sustain per capita economic growth following national circumstances and, in particular, at least 7 percent gross domestic product growth per annum in the least developed countries", and the unemployment rate is for the Target 8.5 “By 2030, achieve full and productive employment and decent work for all women and men, including for young people and persons with disabilities, and equal pay for work of equal value” [1].

Thus, to model the level of macroeconomic security, according to the authors, the key indicators of macroeconomic security because of the current state of Ukraine's economy should include the rate of GDP growth, the consumer price index, and the unemployment rate. The next step to determine the level of macroeconomic security is the normalization of indicators, which is carried out by comparing them with specific reference values. As a result, all indicators are reduced to the range of values [0,1]. The normalization process and formulas for its implementation are described in detail in [15]. Next, it is necessary to calculate the subindex of macroeconomic security, which characterizes the level of this component of economic security. Usually, the additive hill method is used for this.

Having previously defined the key theoretical aspects of the research, let's proceed directly to the construction of the model. Since the indicators mentioned above are usually analyzed separately, the authors are faced with the problem of independently building a dynamic system model that will include GDP, inflation index, and unemployment rate indicators.

Let's consider each of these indicators; let's start with GDP as a basis for the model of the Nobel laureate Robert Solow [6] with modifications proposed by Romer [9]. However, Romer's assumptions about human capital and its dynamics should be slightly improved since human capital in a country depends not only on direct investments in innovative activities but also on general expenditures on health care and education of the population. It is also worth considering that the result of funds invested in human capital development is distributed throughout the economy, which is an investment multiplier effect k_m. Thus, the volume of production is calculated using the modified Cobb-Douglas function, taking into account human capital (1), the dynamics of material and human capital are demonstrated by equations (2) and (3), and the level of scientific and technological progress is demonstrated by equation (4) [22].

The next step is to build a model for the unemployment rate. With the use of the distribution of the population between three key groups shared in the scientific literature: employed and unemployed (which together form the economically active population), as well as the economically inactive population since for modeling employment and unemployment, it is essential to take into account social interactions between population groups, including the economically inactive population as a constant source of replenishment of the employed and unemployed people. Each of the population groups changes at each moment of time t; these changes occur due to the movement of the people from the group to group in both directions, as well as due to the exclusion or, on the contrary, the inclusion of particular individuals of one or another group as a result of their migration, death or birth. The coefficients η_{ij}in the dynamic's equations (5), (6), (7) characterize the movement of the population between groups, and the coefficients h_i- the migration and natural movement of the people. For example, the ratio η_{LU}shows the share of the people that, on average, moves from the group of the employed people to the group of the unemployed at time t, and η_{UL}vice versa, the share of the unemployed population that moves to the group of the employed, while the ratio h_L shows the overall rate of change in the number of the group of the employed population not associated with flows to other groups reflected in the model (migration, death). A kinetic model based on the classic Fisher "exchange" equation was used to build a model of the inflation rate, described in detail in [11, 12]. As a result, the dynamics equation (8) was obtained.

To calculate the direct values of the coefficients, auxiliary equations for the GDP growth rate (9), the unemployment rate (10), and the inflation rate (11) were used. The model of system dynamics (1)-(11) was formed from the equations described above:

$$Y(t) = K(t)^{\alpha} H(t)^{\beta} [E(t)L(t)]^{\gamma} \tag{1}$$

$$\frac{dK(t)}{dt} = -\mu_K K(t) + I_K(t), \qquad K(0) = K_0 \tag{2}$$

$$\frac{dH(t)}{dt} = k_m \cdot I_H(t) - \mu_H H(t)\,, H(0) = K_0 \tag{3}$$

$$\frac{dE}{dt} = \theta HE(t), \qquad E(0) = E_0 \tag{4}$$

$$\frac{dL(t)}{dt} = h_L L(t) + \eta_{UL} U(t) + \eta_{OL} O(t) - \eta_{LU} L(t) - \eta_{LO} L(t), \qquad L(0) = L_0 \tag{5}$$

$$\frac{dU(t)}{dt} = h_U U(t) + \eta_{LU} L(t) + \eta_{OU} O(t) - \eta_{UL} U(t) - \eta_{UO} U(t), \qquad U(0) = U_0 \tag{6}$$

$$\frac{dO(t)}{dt} = h_P O(t) + \eta_{LO} L(t) + \eta_{UO} U(t) - \eta_{OL} O(t) - \eta_{OU} O(t), O(0) = O_0 \tag{7}$$

$$\frac{dP(t)}{dt} = k\left(\frac{M(t_0) + \Delta M}{Y(t)}v - P(t_0)\right), \ P(0) = P_0 \quad (8)$$

$$\Delta Y(t) = \frac{Y(t) - Y(t-1)}{Y(t-1)} \cdot 100\% \quad (9)$$

$$UR(t) = \frac{U(t)}{U(t) + L(t)} \cdot 100\% \quad (10)$$

$$IR(t) = \frac{P(t) - P(t-1)}{P(t-1)} \cdot 100\% \quad (11)$$

where *Y(t)* is GDP at time *t*; *K(t)* – the main productive assets, capital at the moment of time *t*; *H(t)* – human capital at time *t* ; *E(t)* is the stock of knowledge available in the economy at time *t* ; *L(t)* is the number of people employed in the economy at time *t* ; α , β and γ– production elasticity coefficients, respectively, for capital *K,* human capital *H* and labor *L;* μ- coefficients of disposal of capital; $I_K(t)$– investments in production capital assets; I_H(t) – costs of human capital ; θ– parameter of scientific productivity; *L(t)* – employed population at time *t* , *U(t)* – unemployed population at time *t;* and *O(t)* is the economically inactive population at time *t; P(t)* is the level of prices in the economy; *k* is the coefficient of acceleration or deceleration of the transition to a new value *P(t)* according to the rate of its change; $M(t_0)$– amount of money supply at a specific initial moment of time t_0; ΔM– change in the money supply over time period *t*; *v* – speed of money circulation; $\Delta Y(t)$– GDP growth rate; $UR(t)$– unemployment rate; $IR(t)$- inflation rate.

After discretization of the model, selection of parameters based on historical data for 2017-2021, and some simple linear transformations, the following specified model (12)-(22) was obtain:

$$Y(t) = K(t)^{0,477}H(t)^{0,303}[E(t)L(t)]^{0,219} \quad (12)$$

$$K(t) = 0{,}966 \cdot K(t-1) + I_K(t-1) \quad (13)$$

$$H(t) = 0{,}983 \cdot H(t-1) + 6{,}962 \cdot I_H(t-1) \quad (14)$$

$$E(t) = 4{,}83 \cdot 10^{-9} \cdot H(t-1) \cdot E(t-1) + E(t-1) \quad (15)$$

$$L(t) = 0{,}923 \cdot L(t-1) + 0{,}57 \cdot U(t-1) + 0{,}013 \cdot O(t-1) \quad (16)$$

$$U(t) = 0{,}43 \cdot U(t-1) + 3{,}916 \cdot 10^{-4} \cdot L(t-1) + 0{,}07 \cdot O(t-1) \quad (17)$$

$$O(t) = 0{,}96 \cdot O(t-1) + 0{,}0858 \cdot L(t-1) + 3{,}86 \cdot 10^{-5} \cdot U(t-1) \quad (18)$$

$$P(t) = 0{,}85 \cdot \frac{M(t)}{Y(t)} + 0{,}693 \cdot P(t-1) \quad (19)$$

$$\Delta Y(t) = \frac{Y(t) - Y(t-1)}{Y(t-1)} \cdot 100\% \quad (20)$$

$$UR(t) = \frac{U(t)}{U(t) + L(t)} \cdot 100\% \quad (21)$$

$$IR(t) = \frac{P(t) - P(t-1)}{P(t-1)} \cdot 100\% \quad (22)$$

Now it is worth evaluating the accuracy of the model based on already-known data and finding errors that will characterize the adequacy of the model (Table 1).

Table 1. Relative errors of the model.

Years	2018	2019	2020	2021	$\bar{\Delta}$
ΔGDP Y(t), %	0.065%	0.100%	5.550%	3.217%	2.233%
Δ Employed population L(t), %	2.054%	4.664%	1.955%	0.952%	2.406%
Δ Unemployed population U(t), %	4.739%	0.054%	7.848%	4.990%	4.408%
Δ Ek inactive population O(t), %	10.927%	9.110%	5.273%	0.039%	6.337%
Δ Price level (until December of the previous year) P(t), %	6.371%	0.640%	3.920%	2.488%	3.355%

Considering the given errors, this model is valid. The next step is to prepare data for building a forecast. The initial values of all model variables ware set. Taking the approximate indicators of 2022 as a starting point. The initial values are:

$$Y(0) = 3105879{,}57;\ K(0) = 5775764{,}08;\ H(0) = 19769386{,}98;$$
$$E(0) = 0{,}2855;\ P(0) = 1{,}671;\ M(0) = 2501621{,}41$$
$$L(0) = 10878553;\ U(0) = 3626184;\ O(0) = 12099702.$$

As a forecasting horizon, a medium-term perspective for three years were choose, $t \in [0{,}3]$. It is possible to perform prognostic modeling in any software, so in this case, in order to automate calculations, the Python programming language was used.

Also, it should be noted that since the selection of the parameters of this model was carried out on the indicators of the pre-war period, the forecast obtained on its basis assumes that the specifics of the national economy have not changed, and the previous dynamics of the analyzed indicators will be preserved. In this situation, a scenario approach is becoming relevant [23], using which it is possible to consider the different duration of the high level of security risks and their impact on economic activity and the pace of economic recovery. The introduction of such an approach will contribute to obtaining more relevant forecasts of indicators of macroeconomic security and the immediate level of macroeconomic security.

In the case of further developing the basic and alternative-unfavorable scenarios, during the construction of which assumptions will be taken into account regarding the different intensities and duration of hostilities.

At this stage, various state and international institutions make different assumptions in their forecasts. Therefore, by analyzing the assumptions of the forecasts of the National Bank of Ukraine [17], the Ministry of Economy of Ukraine, and the International Monetary Fund [19], it can be concluded that these organizations consider two possible scenarios of the development of events:

1. *Basic* – provides for a significant reduction of security risks from the beginning of 2024; that is, by the end of 2023, the acute phase of the war will end, and further escalation of the conflict is not expected;

2. *Unfavorable* – considers the duration of the acute active phase of the war for at least three-quarters of 2024.

After calculating the scenario forecasts, it is worth averaging the obtained indicators to formulate the highest quality and most precise possible conclusion regarding the future state of the national economy and the level of macroeconomic security. To implement these actions, calculate the mathematical expectation of three key indicators of macroeconomic security; for this, use the indicators according to the basic and unfavorable scenario. It is necessary to determine the probability of the implementation of the scenarios. Since the scenarios' assumptions are based mainly on the war's progress, it is necessary to investigate the opinions of experts in this field. Some are inclined to think that the end of the active phase should be expected already in 2023 [24, 25], which is foreseen by the basic scenario, while others believe that the completion will not take place before 2024 [26, 27], the opinions on this issue are divided almost equally. Given such a division, it is reasonable to set values equal to 0.5, i.e., $p_1 = p_2 = 0{,}5$.

So, having commented on all the key moments of the calculations, make a forecast based on the model (12)-(22); this forecast in Table 2 is shown as a potential one. The basic and alternative forecasts (Table 2) are obtained from the adjusted model (12)-(22) following the assumptions of the forecasts, the principle of calculating the mathematical expectation as described above.

Table 2. Forecasts of dynamics of indicators of macroeconomic security.

Indexes	Types of forecasts	2022	2023	2024	2025
Unemployment rate, %	Potential prognosis	25.00	16.43	13.00	11.76
	Basic forecast	25.00	19.25	15,26	12.67
	Alternative forecast	25.00	19.35	15,24	12.46
	Math. expectation	25.00	19.3	15.25	12.57
CPI, p.p.	Potential prognosis	26.60	12.07	8.65	6.61
	Basic forecast	26.60	17.98	12.50	8.33
	Alternative forecast	26.60	21.87	18.36	14.09
	Math. expectation	26.60	19.93	15.43	11.21
GDP growth, p.p.	Potential prognosis	-25	7.66	8.23	7.57
	Basic forecast	-25	-0.90	6.37	8.91
	Alternative forecast	-25	-6.53	3.76	7.35
	Math. expectation	-25	-3.72	5.07	8.13

To get the level of macroeconomic security, it is necessary to normalize the indicators according to the Methods [15] and calculate the subindex of macroeconomic security using the additive convolution method for the weighting factors choose equal numbers, i.e., 1/3, since all three indicators play an essential role in macroeconomic security and reflect a particular sphere of the national economy (Table 3).

Table 3. Forecasts of normalized indicators of macroeconomic security.

Indexes	Types of forecasts	2022	2023	2024	2025
Subindex	Potential prognosis	0.054	0.436	0.502	0.549
	Basic forecast	0.054	0.103	0.437	0.508
	Alternative forecast	0.054	0.068	0.342	0.438
	Math. expectation	0.054	0.073	0.393	0.461

So, let's analyze the obtained forecasts: the potential normalized indicator of the level of unemployment during the forecast period is within critical limits; the CPI indicator is at a crucial level in 2022 and 2023, at a dangerous level in 2024, and an unsatisfactory grade in 2025; the GDP growth rate indicator is at a minimal or hazardous level in 2022, at an optimal level in 2023-2025. The integral subindex of macroeconomic security is growing over the entire forecast period. The level of macroeconomic security in 2022 is hazardous; in 2023, it rises to the level of danger and, in the following years, is at an unsatisfactory level.

Next, analyze the results obtained from scenario forecasting. For the sake of clarity, the normalized indicators of macroeconomic security according to the basic, alternative scenarios and mathematical expectations in Fig. 1. The indicators in the figure are grouped by color, so different shades of blue represent indicators of GDP growth, green - CPI, yellow - the unemployment rate. It is immediately worth noting that the normalized indicator of the essential level of unemployment according to various forecasts is unchanged and, during the forecast period, is within critical limits because, as can be seen from Table 3, the actual value of the indicator does not change significantly. As for the normalized CPI indicator, according to the basic scenario, it is at a critical level in 2022-2024 and at a dangerous level in 2025; according to an alternative scenario, by analogy with the unemployment rate indicator, it is always at a critical safety level.

The situation is better with the GDP growth indicator: according to the base scenario, this indicator is at a minimal or hazardous level in 2022, a critical level in 2023, and an optimal level in 2024 and 2025. According to the assumptions of the alternative scenario, the normalized rate of GDP growth is at a minimal or hazardous level in 2022-2023, at a satisfactory level in 2024, and an optimal level in 2025. The mathematical expectation repeats the dynamics of the alternative scenario with slightly higher values of the indicators.

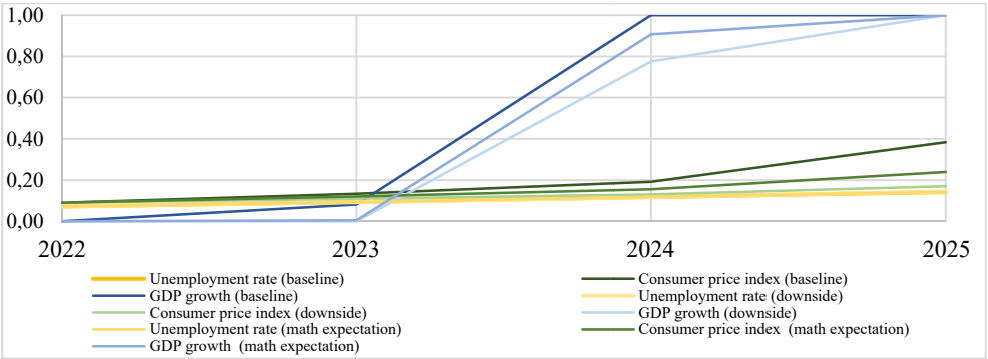

Fig. 1. Standard indicators of macroeconomic security, 2022-2025.

So, to compare all the forecasts obtained in this work, in Fig. 2, the dynamics of the simplified integral subindex of macroeconomic security in 2023-2025. For convenience, highlighted the area of a satisfactory and optimal state of macroeconomic security and immediately drew the disappointing conclusion that over the entire forecast horizon, none of the forecasts reaches this area, and even the indicators calculated under the baseline scenario, the potential values do not catch up. The lowest hands are predicted in 2023, according to all calculations. It is worth noting that even the potential value of the sub-index is not above the danger zone. Let's analyze the scenario forecasts and mathematical expectations in more detail: Yes, in 2023, according to these calculations, the level of macroeconomic security is critical; in 2024, it rises to the level of danger according to the alternative forecast and mathematical expectations, and to unsatisfactory according to the basic one; and in 2025 is at an insufficient level according to three types of calculations.

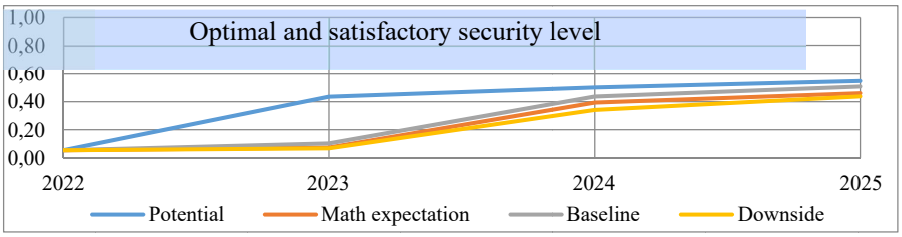

Fig. 2. Comparison of various forecasts of the integral subindex of macroeconomic security, 2022-2025.

Therefore, forecasts of the level of macroeconomic security in the medium term could be better. As a result of the significant destruction of the main production assets, infrastructure, mining of large areas of agricultural land, population migration abroad, even the potential pace of economic recovery, which does not take into account the current destruction, low domestic demand, and limited export opportunities, is not characterized by a satisfactory or optimal level of macroeconomic security. Thus, there is an urgent need to introduce a system of measures that will contribute to the fastest possible recovery of Ukraine's national economy and reconstruction.

Now let's compare the obtained forecast with the estimates of various companies and institutions to assess its adequacy. Thus, Table 4 contains estimates of key macroeconomic security indicators of international institutions, state institutions, and private companies [17, 19, 28]. This comparison makes it possible to demonstrate insignificant deviations of indicators; that is, it can be considered appropriate to formulate a conclusion about the adequacy of forecasts for 2023.

Table 4. Comparison of macroeconomic forecasts for 2023.

Indexes	GDP growth rate, p.p.	The inflation rate, p.p.	Unemployment rate according to the ILO, %
MFV	-1	20	20.9
The World Bank	0.5	18	-
Ministry of Economy	-1.2	24.1	18.8
NBU	2	14.8	18.3
ICU	4	24	-
Dragon Capital	-5	18	-
Concorde Capital	-7	22	-
SenseBank	5.5	18	-
Consensus (average)	-0.28	19.86	19.33
Consensus (median)	-0.25	19.00	18.80
Mathematical expectations of the author's forecasts	-3.72	19.93	19.3

To compare the indicators calculated for the entire forecast period, use the estimates of the National Bank of Ukraine, the IMF, and the Ministry of Economy of Ukraine. As can be seen from Table 5, indicators are variable, as they are based on different assumptions. Therefore, after calculating the average values and comparing them with the mathematical expectation of the author's forecast, it is possible to conclude that the forecast is adequate for 2023 but also 2024 and 2025.

Table 5. Comparison of forecasts of key indicators for 2023-2025.

Indexes	Forecasts	2023	2024	2025
CPI, p.p.	NBU	14.80	9.60	6.00
	The IMF is unfavorable	27.60	25.30	17.20
	IMF basic	20.00	12.50	8.00
	Ministry of Economy	24.10	12,20	7.80
	Average	21.63	14.90	9.75
	Math. expectation	19.93	15.43	11.21
GDP growth, p.p.	NBU	2.00	4.30	6.40
	The IMF is unfavorable	-10.00	-2.00	0.00
	IMF basic	-1.00	3.20	6.50
	Ministry of Economy	-1.16	11.49	9.81
	Average	-2.54	4.25	5.68
	Math. expectation	-3.72	5.07	8.13
Unemployment rate, %	NBU	18.30	16.50	14.70
	IMF basic	20.90	11.90	9.70
	Ministry of Economy	18.80	13.20	12.40
	Average	19.33	13.87	12.27
	Math. expectation	19.30	15.25	12.57

Therefore, the obtained forecasts are quite qualitative; based on them, it is advisable to develop recommendations for increasing macroeconomic security.

Adequacy of the forecast, it is necessary to discuss a system of measures to speed up the recovery of the Ukrainian economy and increase macroeconomic security. The key goals of these measures are to restore the production potential, stabilize the financial market and increase the employment of the population. A detailed plan for the recovery of the Ukrainian economy with the grouping of goals and measures into short-term, medium-term, and strategic ones, as well as a preliminary assessment of the cost of the proposed measures and the economic effect of their implementation, is presented in the Draft Plan for the Recovery of Ukraine, which was developed by the National Council for the Recovery of Ukraine from the Consequences of War [29]. Preliminary estimates of key indicators of macroeconomic security are presented in the document [29], so let's immediately give the values of normalized indicators and calculations of the subindex, taking into account the implementation of measures (Table 6).

Table 6. Normalized indicators of macroeconomic security under the condition of implementation of the proposed system of measures for 2023-2025.

Years	2023	2024	2025
Unemployment rate	0.105	0.129	0.157
CPI	0.128	0.202	0.408
GDP growth	0.991	1.000	1.000
Subindex	0.408	0.444	0.522

The estimates of the improved forecast's macroeconomic security level were compared with previously considered forecasts (Fig. 3).

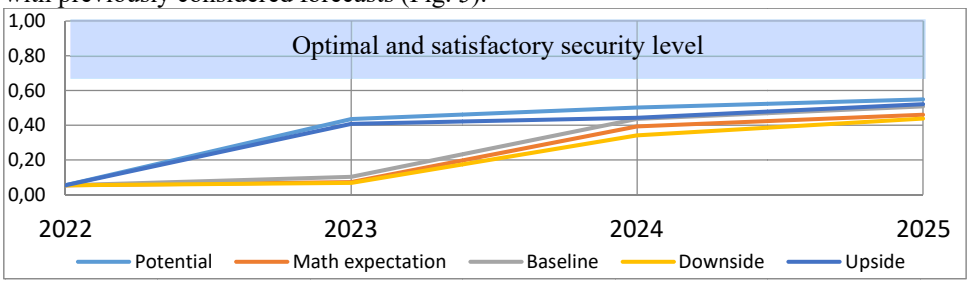

Fig. 3. Comparison of various forecasts of the integral subindex of macroeconomic security, 2022-2025.

Thus, the proposed plan to restore the Ukrainian economy will contribute to improving the level of macroeconomic security. Effective implementation of such a program will contribute to accelerated growth of the population's income level and reduced unemployment faster than calculated by mathematical expectation. Significant inflationary consequences will not accompany the increase in income, as the price pressure will be neutralized by a favorable currency situation, allowing the National Bank of Ukraine to ease monetary policy rapidly. However, it is worth understanding that security risks, the amount of external financing from creditors and donors, and the success of implementing these recommendations play a decisive role in the pace of economic recovery and the level of macroeconomic security. Of course, it should be noted that most of these costs have yet to be foreseen by any of the international institutions that provide financial assistance to Ukraine. That is, sources of financing have yet to be found to a greater extent. However, targeted investment funds are already being actively created.

4 Conclusions

In the course of this study, based on the selected three key indicators of macroeconomic security (GDP growth rate, inflation rate, and unemployment rate), by improving the economic growth model of Romer, using the kinetic model of inflation and building the author's model for evaluating and forecasting the dynamics of population groups, a dynamic system model was built, which allows both are evaluating and forecasting macroeconomic security.

By selecting the parameters of the model based on historical data for 2017-2021, assessing the accuracy of the model, and modeling the formed system of economic indicators of macroeconomic security of Ukraine, its high accuracy, efficiency, and validity were confirmed, despite the inherent aggregation of macroeconomic models. The model's average error equals 3.25%, the maximum one is 10.927% for the inactive population in 2018.

Conducted prognostic modeling for the medium-term perspective in 3 years, i.e., 2023-2025. Due to the model's forecasts CPI and the Unemployment rate are going to decrease by 43.753% and 34.87%, respectively. Also, a scenario approach based on different levels of security risks was introduced and the indicator trends were analyzed. The proposed actions made it possible to reveal the unsatisfactory state of macroeconomic security and the difficulty in achieving Ukraine's sustainable development goals. Potentially, the level of the macroeconomic security would increase by 13.48%. The obtained results indicate the need to implement measures to improve Ukraine's macroeconomic situation. Such a system of measurements has already been proposed in "Project of Ukraine Recovery Plan. National Council for the Restoration of Ukraine from the Consequences of War". However, the key problem at this stage is the search for funding sources, the availability of which will entirely depend on the further recovery of the national economy.

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