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Modeling the Economic Sustainability of the Macro System (for Example Ukraine)

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ABSTRACT

For normal livelihoods, social and economic systems must h economic stability that ensures their existence and developm under the influence of various destabilizing factors of the exte and internal environments. Managing economic sustainability wil effective if it is based on an objective and reliable assessment. purpose of the article is to outline the the simulation of assessment content of the economic stability of the macroecono system. Modeling data was provided by official data of Ukraine. study object is the simulation process, which involves a sequenc model development for assessing economic sustainability and application of mathematical methods that led to this assessm Many scientists, economists and mathematicians solved assessing economic stability problem, but did not pay attentior its structural content. The complexity of the estimation is provi by an appropriate system of partial and integral indicators t reflect the various system properties, taking into account the cau relationships of these indicators with the influence factors, wh determines the homeostasis of the internal and exte environments, and the rating proximity of these indicators to sc structural normative economic change. Sustainability is prerequisite for its conservation and enforcement. Macrosystem economic stability if its corresponding structure is maintained du the operation period. This basic idea is realized in the mode process the assessment of the economic stability of macroeconomic system. It is necessary to determine the dyna structural standard of the states of economic stability of macroeconomic system and in relation to it to make mathemat

convolution of partial indicators on the computation basis of Spirman and Kendall rank coefficients, and their combination. The complexity of the mathematical model for assessing economic sustainability is achieved by taking into account both the general economic stability level of the macroeconomic system, which is calculated as a taxonomic indicator of development, and by means of an economic stability integral indicator structure.

INTRODUCTION

Economic stability is one of the main life conditions of any socio-economic system, regardless of its management level. Of course, such systems operates in conditions of uncertainty, since it is under the influence of many factors, both external and internal environments, and their actions can not be uniquely predicted. Perturbing environmental influences cause deviation of the system from the equilibrium position. In this regard, an important issue is the stability of the economic system as a whole. To manage the stability of the macroeconomic system, it is necessary to have an objective assessment that is multidimensional and multicriteria and takes into account the structure. An statistical data analysis of the Ukraine economy (Official site of the Ministry of Economic Development and Trade of Ukraine) demonstrates the need in solving such a problem. According to official statistics, the change in the macroeconomic indicators in January-March 2019 to the corresponding previous year period was as follows: industrial production -0.9%, gross agricultural products 3.4%, retail turnover 7.4%, real wages 10, 1%, capital investments 16.4%, exports of goods and services 7.8%, goods and services imports 7,5%. But, against the growth backdrop of these key macroeconomic indicators, there are significant negatives, namely: producers expect the impact of such constraints on the production of factors as a lack of raw materials and financial constraints, while the shortage effect of labor force will increase. The negative destabilizing economic sustainability factors include: external environment deterioration, devaluation processes against the backdrop of complications with the external borrowings implementation, aggravation of the situation in the east, logistical problems. The globalization process is complicated by the current financial and political instability and the economic crisis, the development dynamism of most areas of activity, rigid competition and the variability of the environment. All this threatens the sustainable development of industrial enterprises and entire industries. Therefore, to diagnose the macrosystem economic stability only by the indicators levels is not objective, it is necessary to take into account the dynamics of the processes that occur, which are reflected in the change rates ratio of key macroeconomic indicators.

1. LITERATURE REVIEW

Ukraine scientists actively studied the economic stability problems, among them it is possible to distinguish the works of O. Arefyeva (2011), S. Ramazanov (2012), T. Ponomarenko (2016), V. Ivanov (2010), V. Danilenko (2011), T. Miroshnichenko (2011), V. Margasova (2014), S. Kozlovskyi (2010), N. Shandova (2014), R. Howarth (2012), E. Stockhammer (1997), L. Hassani (2019). It is necessary to proceed from the assumption that economic stability is not an end in itself but means of ensuring sustainable economic growth and raising the level and population life quality. Therefore, not only the current economy state is important, but also the methods by which it is achieved: privileges, subsidies for investing in people, in science, in infrastructure, due to the resources exhaustion of their own development or on the improving basis efficiency of the economic entities functioning, the competitive environment formation, and more.

The scientific basis for solving the ensuring economic sustainability problem are modern theories, applied developments and practical actions of the Council for the Ukraine Productive

Forces Study of the Ukraine National Academy of Sciences, State Enterprise Institute of Economics and Forecasting of the Ukraine National Academy of Sciences, National Institute for Strategic Studies, etc.

But despite a large number of studies, there are currently no analytical grounds for determining the economic sustainability of an enterprise and its evaluation, taking into account the structural content. In order to solve these problems, it is necessary to clarify the notion meaningful nature of economic stability and to form informational and analytical support for evaluation for an objective determination of its level.

2. DATA AND METHODOLOGY

An important developing component a mechanism for ensuring the macroeconomic system stability is system indicators development that characterize the state and trends of its change under the influence of positive and negative internal and external factors. Economic sustainability is an important characteristic of all economic systems in different management levels. This characteristic is reflected in the system of partial and integral indicators that characterize various properties of the system; the causal relationships between these indicators and the factors of influence determine the homeostasis of the internal and external environment, and the proximity of the rate of change of these indicators to some structural regulatory economic sustainability is a condition for its preservation and maintenance.

For a detailed economic stability study it is necessary to analyze its structure. Macrosystem has economic stability if its appropriate structure is maintained during its operation. To ensure economic stability, the change pace of its key indicators must comply with some structural standards. Therefore, in order to determine the integral index of the structure of the economic stability of the macrosystem, it is advisable to use the method of I. Suroezhyn to determine the system of indicators of efficiency and quality, based on the idea of the existence of a normative order of the changes rates in partial indices (Suroezhyn, 1970). In other words, the macrosystem will have economic stability if the regulatory changes rates ratio to its most important partial indicators is maintained. Consequently, each macrosystem state is characterized by some separate structural norm, which is a roraned system of rates of changes in indicators that reflect the content of economic stability. The formation of this structural dynamic norm should be based on the laws of the processes development that are characteristic of this or that state. Let's consider in detail the structural dynamic norm formation of Ukraine economic stability in crisis conditions.

The well-known Ukraine scientist A. Melnyk characterizing the macroeconomic systems development, argues that the change rate in average wages (Q_{aw}) should be less than the rate of change in the volume of industrial products sold (Q_{ps}) and, accordingly, the rate of change in nominal GDP (Q_{ngdp}). Only under such conditions will an increase in the rate of change in direct investment in Ukraine (Q_i) (Melnyk, 2014):

$$Q_i > Q_{ngdp} > Q_{ps} > Q_{aw} > 100\ \%.$$

O. Smulov draws attention to the financial indicators, since the growth rate of positive dynamics of direct investments in Ukraine (Q_i) depends on the reduction of the reduction rate of the country's public debt (Q_{pd}). At the same time, the pace of changes in the foreign exchange reserves of Ukraine (Q_{fer}) should be higher than the changes rates in the country's public debt and lower than the rates of change in the volume of industrial products sold (Q_{ps}) (Smulov, 2003):

$$Q_i > Q_{ps} > Q_{fex} > Q_{pd} > 100\ \%.$$

A. Halchynskyi believes that the causes of crises of the world development are low rates of change in the volume of products sold, which in turn affects a decrease in exports of goods and services and an increase in imports. Therefore, to get out of crisis conditions, it is necessary to lay strength to increase the rate of change in the volume of sales (Q_{ps}) over the rate of change in exports (Q_e) and the import of goods and services (Q_{im}) and the rate of change in government debt (Q_{nd}) (Halchynskyi, 2009):

$$Q_{ps} > Q_{nd} > Q_e > Q_{im} > 100\ \%.$$

According to I. Otenko in an era of crisis, a positive factor contributing to the acceleration of exit from his influence is an increase in the rate of change in average salary (Q_{as}) with a simultaneous decrease in the rate of change in wage arrears (Q_{wa}) (Otenko et al., 2007):

$$Q_{as} > Q_{wa} > 100\ \%.$$

The leading scientist in modeling and methodology for the sustainable development of the economy of Ukraine S. Ramazanov argues that the growth in dynamics is lower than the ratio of the rates of change in public debt of the country (Q_{nd}), the volume of industrial products sold (Q_{ps}) and the ratio of changes in nominal GDP recorded above (Q_{ngdp}) and direct investment (Q_i) in Ukraine reflect a positive trend in the development of the enterprise (Ramazanov et al., 2012):

$$Q_i > Q_{ngdp} > Q_{ps} > Q_{nd} > 100\ \%.$$

O. Lynnyk draws attention to the rate of change in the unemployment rate (Q_{ur}) and what the increase in the rate of change in average salary (Q_{as}) depends on their decrease, according to the scientist (Lynnyk et al., 2013):

$$Q_{as} > Q_{ur} > 100\ \%.$$

Based on the analysis of scientific and practical literature on the ratio of the rate of change of economic indicators, the structural dynamic norm of economic sustainability of Ukraine in crisis conditions was substantiated, presented in Table 1.

Table 1. Structural standard of economic sustainability of Ukraine in crisis conditions

Private indicator of economic sustainability	*Rank indicator in the standard*
Direct investment in Ukraine (Q_i)	1
Nominal GDP (Q_{ngdp})	2
Volume of industrial products sold (Q_{ps})	3
Gold reserves of the country (Q_{gr})	4
National debt (Q_{nd})	5
Exports of goods and services (Q_e)	6
Imports of goods and services (Q_{im})	7
Average salary (Q_{as})	8
Wage arrears (Q_{wa})	9
Unemployment rate (Q_{ur})	10

Source: Melnyk, 2014; Smulov, 2003; Halchynskyi, 2009; Otenko et al., 2007; Ramazanov et al., 2012;Lynnyk et al., 2013.

In fig. 1 shows the dynamics of the basic indices of macroeconomic indicators included in the structural standard (Table 1), while the basis for the calculation was 2007.

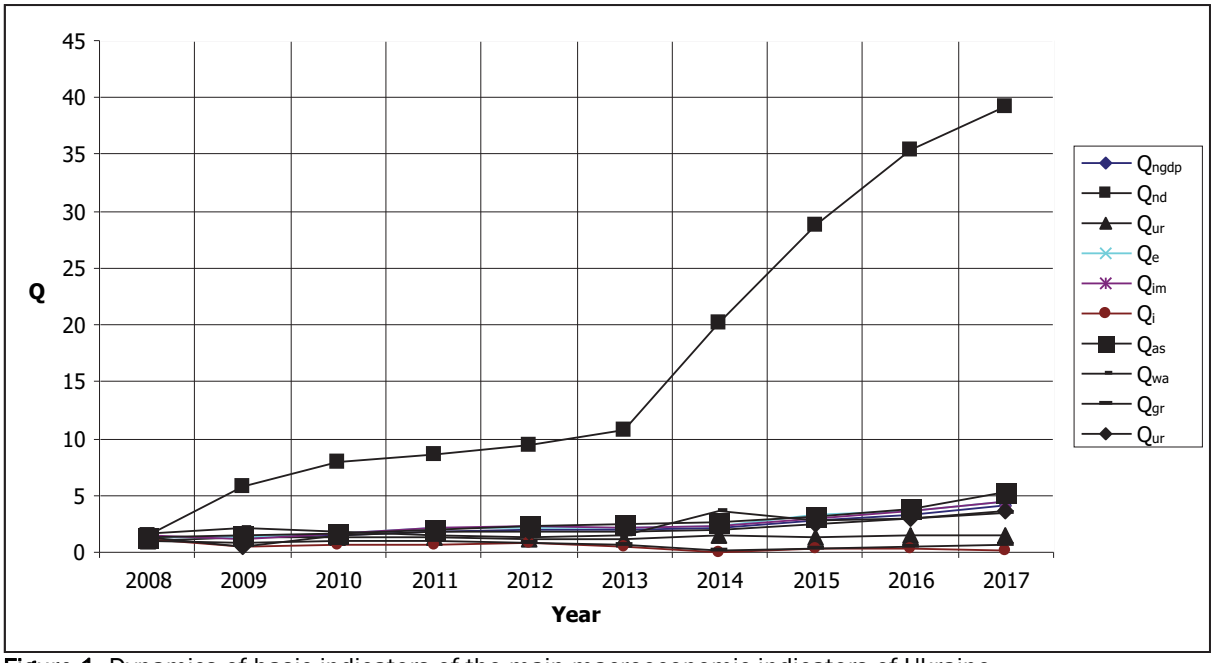

Figure 1. Dynamics of basic indicators of the main macroeconomic indicators of Ukraine

Source: http://me.gov.ua

According to fig. 1 the largest change compared with the base period has suffered the indicator of public debt of the country (Q_{nd}), namely in 2017 it reached a record high of 40% compared with the base year 2007. The reason for this phenomenon is an increase in government spending without a corresponding increase in government revenue; the impact of political business cycles; cyclical downturns and automatic stabilizers of the economy; tax cuts to stimulate the economy without a corresponding reduction in government spending. The dynamics of a number of macroeconomic indicators are also not at the best - changes such as direct investment in Ukraine (Q_i), nominal GDP (Q_{ngdp}), volume of industrial products sold (Q_{ps}), gold and foreign exchange reserves of the country (Q_{gr}), and exports of goods and services (Q_e), the import of goods and services (Q_{im}) indicates that despite the fact that from a base year (2007) from a few to ten years, key macroeconomic indicators, which should grow, have not undergone a significant increase, is negative th event in the life of the state. In general, it is difficult to talk about the economic sustainability of the country, based on the analysis of the dynamics of the basic indices of the main macroeconomic indicators of Ukraine (Kosianchuk, 2011).

Often the level of economic sustainability is calculated using generalized or integral indicators. Since the concept of economic sustainability is complex and requires a systematic approach to its definition, its value cannot be measured with the help of some generalizing economic indicator. Consequently, the level of economic sustainability should be determined by constructing an integral indicator. The most common methods for calculating integral indicators in economics are based on the additive and multiplicative complete folding of a system of particular indicators, as well as special mathematical methods such as the taxonomic method for constructing an integral development indicator and the Harrington quality indicator. It is known that the system of private indicators allows for in-depth study of the elementary features of an object in economics, and a reduction of one magnitude using a mathematical method synthesizes the general characteristic of this object. Undoubtedly, the convolution of particular indices into one magnitude can be accomplished by various mathematical methods, namely: factor analysis, canonical correlations, multidimensional scaling, cluster and discriminant analyzes, that is, multidimensional statistical

analysis methods, as well as using heuristic methods for reducing dimensionality (Ponomarenko et al., 2009). But these methods perform an incomplete reduction of the characteristics of an object in the economy; their use can significantly reduce the number of signs, but in the aggregate there is always more than one sign.

When constructing integral indicators in the economy, it is advisable to use the recommendations of F. Borodkin and S. Ayvazian for the development of social indicators (Borodkin et al., 2006). They recommend the use of unified scales, which make it possible to turn individual indicators into a dimensionless scale (Borodkin et al., 2006). They claim that the unification of the scale is its transformation (transfer of origin and change of scale), as a result of which the area of $[0; N]$, possible measurement values, where N is always limited to the segment where the number is assigned and indicates the span of the new scale. At the same time, the zero value (origin) of the transformed indicator should correspond to the lowest quality of this property, and the value equal to the highest quality – N. They also believe that the specific choice of a unified transformation depends on which of the three types the indicator being analyzed relates to. A separate indicator can be associated with the synthesized quality of a monotonously increasing dependence, a monotonously decreasing or non-monotonic dependence.

F. Borodkin and S. Ayvazyan (2006) recommend: if the dependence monotonously increases, the value of the corresponding unified variable $\tilde{x}$ is determined by the formula: $\tilde{x} = \frac{x - x_{\min}}{x_{\max} - x_{\min}} \cdot N$ where $x_{\min}$, $x_{\max}$ is the smallest and largest value of the indicator, respectively; if the dependence is monotonously decreasing, the value of the corresponding unified variable $\tilde{x}$ is determined by the formula : $\tilde{x} = \frac{x_{\max} - x}{x_{\max} - x_{\min}} \cdot N$; if the dependence is nonmonotonic, the value of the corresponding unified variable $\tilde{x}$ is determined by the formula: $\tilde{x} = \left(1 - \frac{\left|x - x_{opt}\right|}{max\left\{\left(x_{max} - x_{opt}\right), \left(x_{opt} - x_{min}\right)\right\}}\right) \cdot N$.

The problem in these transformations is the establishment of $x_{min}, x_{max}, x_{opt}$, which is possible thanks to a substantive rationale, according to the model, according to the existing standards. The Harrington method belongs to this group of mathematical methods that construct an integral index. Indeed, the Harrington method has been successfully applied in various fields of human activity, particularly, in economics. This method provides in-depth knowledge of the economic object essence for which the integral indicator is calculated, and the transformation function is $y_{ij} = e^{-e^{-x_{ij}}}$, where x_{ij} – is the value of the economic indicator.

Moreover, the authors of this article modified the Harrington transformation function for different cases of trends in the values of economic indicators. For two-sided asymmetrical trends in the values of an economic indicator, the following conversion functions are recommended:

$$y_{ij} = \begin{cases} 100 \cdot e^{-3\left(\frac{x_{ij} - a_i}{b_i - a_i}\right)^2}, if\ x_{ij} \le a_i, b_i < a_i, \\ 100 \cdot e^{-3\left(\frac{x_{ij} - a_i}{c_i - a_i}\right)^2}, if\ x_{ij} \ge a_i, c_i > a_i, \end{cases}$$

Where a_i, b_i, c_i are the reference values: a_i - the best value of the indicator x_{ij} at which the conversion function reaches the highest value of 1 (100%); $b_i, c_i \ (b_i < c_i)$- unsatisfactory value of the indicator x_{ij} (on opposite sides of the best), at which the conversion function takes on a value not more than 0.05 (5%). If the change in the values of an economic indicator has a symmetrical tendency, the type of conversion function is simplified $y_{ij} = 100 \cdot e^{-3\left(\frac{x_{ij}-a_i}{b_i-a_i}\right)^2}$, herewith $a_i = \frac{b_i + c_i}{2}$. If the change in the values of an economic indicator is monotonous, that is, it either increases or decreases, then a monotonic conversion function of the logistic function type is recommended: $y_{ij} = \frac{100}{1+e^{-\frac{x_{ij}-p_i}{q_i-p_i}}}$ -, where q_i is the value of the index x_{ij} at which the conversion function takes on a value not less than 0.95 (95%); p_i is the value of the index x_{ij} at which the conversion function takes a value of 0.5 (50%) (Ponomarenko et al., 2009).

In this method, complexity arises in the process of constructing a scale of indicators` transformations, defining the main points of indicators` phase changes, defining individual transformation functions, and defining a generalized transformation function.

To another group of integral indicators calculation methods in economics we can consider the V. Pluty method that construct a taxonomic indicator of development. Despite the widespread criticism of this method, it is the most popular in the applications that calculate the integral indicators in the economy. The basic idea of this method is as follows:

- definition of stimulants, disincentives, nominating among economic indicators $X = \left(x_{ij}\right), i = \overline{1,m}, \ j = \overline{1,n}$, where i is the indicator is for the j period or in the j object;
- the formation of the standard according to the criterion MiniMax;
- standardization of indicators: $Z = \left(z_{ij}\right)$; $z_{ij} = \frac{x_{ij} - \overline{x_i}}{\sigma_i}, \overline{x_i} = \frac{1}{n}\sum_{j=1}^{n} x_{ij}, \sigma_i = \sqrt{\frac{\sum_{j=1}^{n}\left(x_{ij} - \overline{x_i}\right)^2}{n}}$;
- convolution of the values in the integral indicator: $d_j = \left(\sum_{i=1}^{m}\left(z_{ij} - z_{i0}\right)^2\right)^{\frac{1}{2}}$; $\overline{d} = \frac{1}{n}\sum_{j=1}^{n} d_j$;

$\delta = \overline{d}$; $s_d = \left(\frac{1}{n}\sum_{j=1}^{n}\left(d_j - \delta\right)^2\right)^{\frac{1}{2}}$; $d = \delta + as_d$; $a = 3$; $d = \delta + as_d$; $I_j = \frac{d_j}{d}$; $I_j^* = 1 - I_j$.

The value of the integral index is in the range from 0 to 1. The closer the value of the integral indicator to 1, the higher the level of development of the given economic object for which this integral indicator is calculated. Repeated application of this method in solving real problems in economics allows the author to conclude that when reference values of individual indicators are formed according to the MiniMax criterion, an integral or relatively low value of the integral indicator relative to generally accepted standards will always be obtained, since features of a separate set of objects are reflected in the value of this indicator. If the reference values are formed theoret-

ically, taking into account the existing conditions, standards, etc., then according to the computational scheme of this mathematical method, there is still a link to the numerical characteristics of the totality of objects. This is a big disadvantage of this method. But a rather simple computational algorithm of the taxonomic indicator of development led to its choice as a method for constructing an integral indicator of the economic sustainability of an enterprise.

The third group of mathematical methods for calculating integral indicators in economics consists of methods, that imply the use of fuzzy sets methods. V. Anfilatov (2003), V. Borysov (2007), S. Sveshnikov and V. Bocharnikov (2007), N. Yarushkinoi (2004), A. Payman (2018), A. Ttianni (2019), H. Bachev (2016), L. Malyarets (2014), L. Synytsia (2010) and other famous experts on the theory of fuzzy sets devoted their works to substantiation of such calculating integral indicators methods in economics. It is known that Professor N. Yarushkina gives 5 ways to implement a generalizing fuzzy logical conclusion in the theory of fuzzy sets (Yarushkina, 2004), and in fact 5 different approaches to the development of an integral indicator based on fuzzy sets. The first approach is based on the Mamdani algorithms (Mamdani), the de-amplification is modeled by the minimum, and the aggregation - by the maximum, the minimax composition of fuzzy sets is used. Each next step of the algorithm receives as input the values of the previous step.

The input receives quantitative values - the output of the same quantitative values. At the fuzzification stage, the values are fuzzy, the degrees of truth are determined, that is, the values of the membership functions for the left-hand sides of each rule (peredposilan). Fuzzy inference is implemented as follows: first, the cut-off level for the left part of each rule is determined, then the cut functions of membership are found. The next stage of the Mamdani algorithm is the composition of the obtained cut functions. And the last stage is the defuzzification process - bringing the data to clarity, for example, using the average center method. The second approach is based on the Tsukamoto algorithm. The initial prerequisites are the same as in the Mamdani algorithm, but it is believed that the membership functions are monotonic. The third approach is based on the algorithm of judgments (Sugeno), while it is believed that the right parts of the inference rules are represented by linear functions. The fourth approach is based on the Larsen algorithm, where a fuzzy implication is modeled using a product operation. The fifth approach is based on a simplified fuzzy inference algorithm, where the source rules are given in the form: if $X \in A_i$ and $Y \in B_i$, then $z = Z_i$ where Z_i is a clear number.

The general procedure for developing an integral indicator based on fuzzy sets is implemented in the following stages (Yarushkina, 2004): 1) formation of a rule base; 2) phasing; 3) aggregation of totals; 4) activation of preliminary findings; 5) fuzzy inference; 6) defuzzification. But all analysts know the truth, namely, for metric (clear) values, to apply mathematical methods of convolution of attributes in economics, which are measured on metric scales, and for nonmetric (fuzzy) values - mathematical methods of convolution of signs, measured in nonmetric scales.

So, using the method of developing taxonomic development indicator for the main macroeconomic indicators characterizing the economic stability of Ukraine, we have the dynamics of this integral indicator, shown in Figure 2.

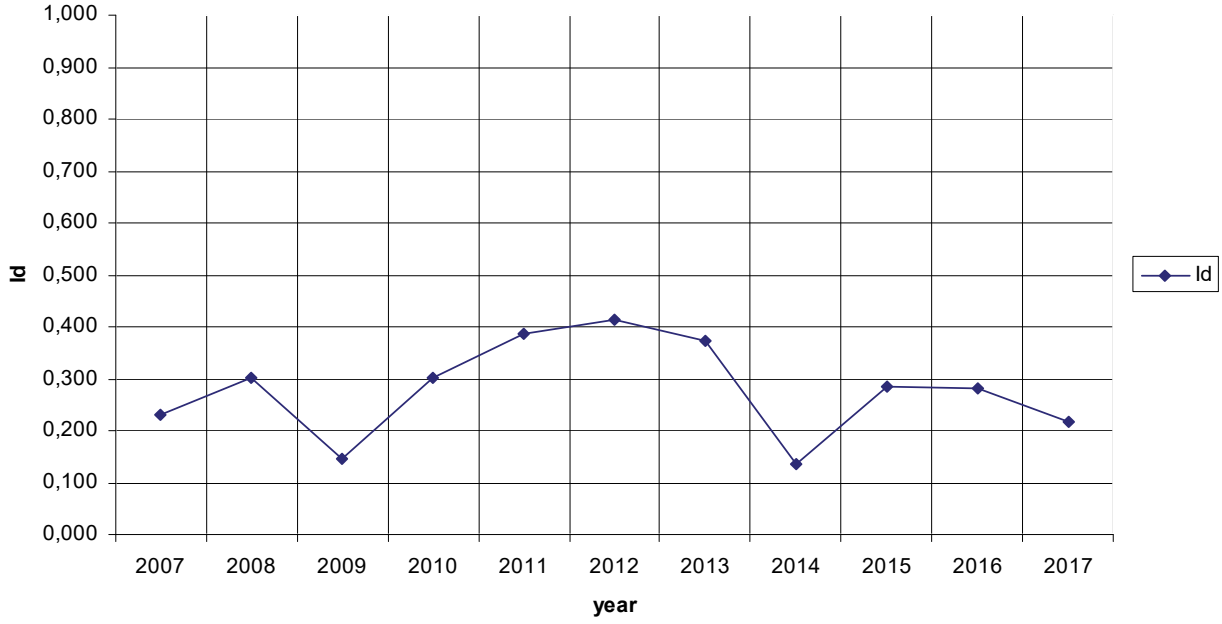

Figure 2. Dynamics of the integral indicator of the general level of economic sustainability (ID) Ukraine

Source: http://me.gov.ua

According to the results of integral estimate of Ukraine economic stability common level (figure 2), it can be affirmed, that from 2000 to 2017 this index decreased the most twice – in 2009 and in 2014. Such state was caused not only by negative effects of internal factors, but also of the external ones. To be exact, the global financial crisis was one of the main reasons. The repeated decrease of common level of economic stability in 2016 was expressly caused by internal factors of national development. That the reason is an insufficient effective consumer demand can be proved by the fact, that final consumption spendings of Ukraine population, which had reduced almost by one third in 2014-2015, only increased by 4,6% in II Q of 2016. It is not enough for renewal of consumer demand in the domestic market. However, despite the difficult situation in the country (a low level of technical and process equipment, inflation processes etc.) a marketable product was being output and almost all of it was being realized. Since the beginning of 2010 the low economic growth takes place in Ukraine. It can be explained by economical stabilization of the country. A new tranche from the International Monetary Fund was favourable to it some way, but taking into account a fact, that Ukraine has to pay an external debt and internal debts and that gold and foreign exchange reserves did not increase, but stayed on the level of former years, so its amount was not enough for solving all the problems of Ukraine economy.

3. APPLICATION OF THE MODEL

For detailed study of economic stability it is necessary to analyze its structure. A country has the economic stability, if the conformable structure of this stability remains unchanged during runtime. For economic stability the rates of changes of its most important indexes have to pass certain structural standards. So, the I. Suroezhyn method of the definition of the system of performance and quality indexes should be used to define integral index of economic stability structure. This method is based on the idea of the existence of normative order of rates of changes in partial indexes (Suroezhyn, 1970). In other words, the economic stability will be guaranteed in country, if

the normative proportion of the rates of changes of its most important indexes remains unchanged.

The evaluation of integral index of economic stability structure of macrosystem on various stages will make possible to estimate the reserves of its providing.

The starting data for evaluation of integral index of economic stability structure is a matrix of basic rates of changes of these 15 most important indexes, which describe this stability during the exploration period, in other words, $Q = (q_{ij})_{15\times10}$ where q_{ij} – index of 'I' factor in 'j' year. The first year of a whole exploration period should be taken in the quality of basic year. On the basis of this matrix, a matrix of ranks is constructed $G = (g_{ij})_{15\times10}$, and the first rank is assigned to the highest value of the index. By using the matrix of ranks we should evaluate Spearman's (r_{cj}) and Kendall`s ($r_{\tau j}$) correlation coefficients:

$r_{cj} = 1 - \frac{6\sum_{i=1}^{N} d_{ij}}{m(m^2-1)}$, where $d_{ij} = p_{ij} - e_i$; $r_{\tau j} = 1 - \frac{4\sum_{i=1}^{N} s_{ij}}{m(m-1)}$, where $d_{ij} = p_{ij} - e_i; s_{ij}$ the number of inversions for 'I' factor for its dynamic structural standard;

Integral index of the structure of economic stability of the enterprise is calculated using a formula:

$$I_{sj} = \frac{(1 + r_{cj})(1 + r_{\tau j})}{4},$$

where $I_{sj} \in [0,1]$ and the more the value of integral index is close to 1, the more the structure of the rates of changes of the most important indexes of economic stability is ordered and the closer it is to the standard. Figure 3 illustrates the dynamics of integral index of economic stability structure of Ukraine in 2008-2017, which was calculated by a described algorithm.

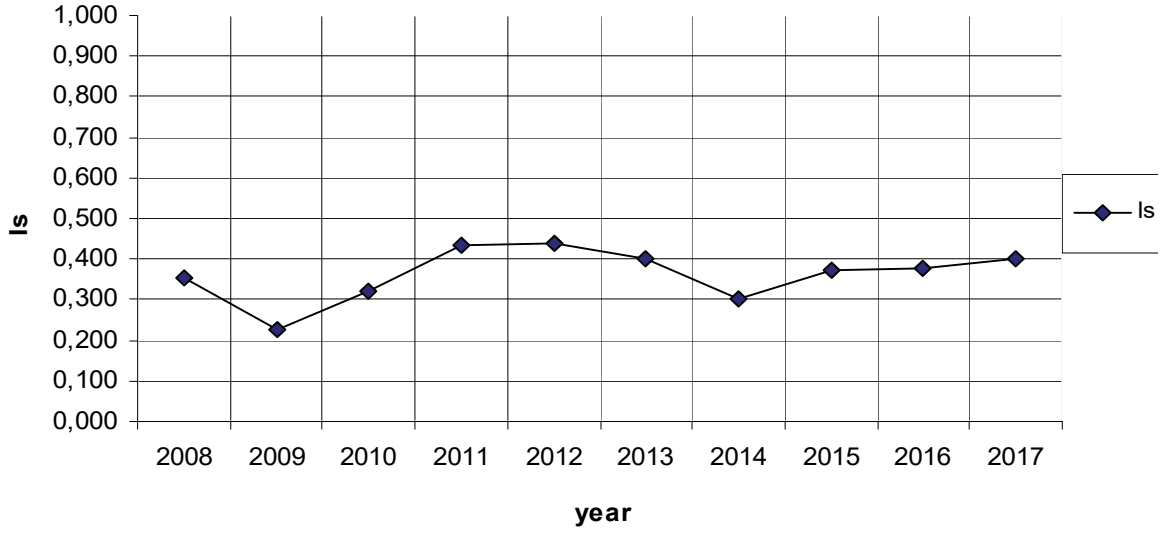

Figure 3. Dynamics of integral index of economic stability structure of Ukraine (I_c)
Source: http://me.gov.ua

As you can see from Fig. 3 starting from 2014 the structural changes, which provide the economic stability of the country, started to have a positive increasing trend, that was directed to increasing of economic stability of Ukraine. The reasons of sizeable decrease of integral index of economic stability structure in 2009 were disbalance of interconnected proportions of changes in the main macroeconomic indexes, namely, the level of inflation was increasing in the country ahead of schedule. The correlation between the rates of changes in the main macroeconomic indexes, that characterize the country's economic stability, has improved somewhat since 2014. Establishing the correct proportions in changing the structure of the economy contributed to the growth of the export potential of the country, albeit at the expense of products from the agricultural sector, the food and pharmaceutical industry.

4. FURTHER CONSIDERATIONS AND DISCUSSION

The assessment of the objectivity of the level of economic stability of the macroeconomic system depends on the structural dynamic norm of this stability. On this subject, it can be debated a lot, but it is objectively recognized that there are regular variations in the structure of macroeconomic systems, which are reflected in the correlations of the rates of changes of the main macroeconomic indexes, that characterize them. Of course, taking into account the different states of economies of different countries, the structural standard of economic stability of individual countries should be their own. Argumentation of the structural norm of economic stability of a separate macroeconomic system is a big labor-intensive research. To manage the economic stability of the macroeconomic system, we must know the acceptable deviations of optimal parameters that provide this stability. These parameters are also different for different macroeconomic systems, but they can be found on the basis of solving a multicriteria optimization problem.

CONCLUSIONS

Thus, modeling the economic stability of the macroeconomic system taking into account its structure is an objective basis for assessing the level of this stability. Such models are the basis for developing of various programs for managing in order to provide the development of a country in future. The proposed models allow to take into account the regularities in the economy and to determine the level of economic stability of an adequately real state. It provides a comparison of the economic stability of different systems both in statics and in dynamics.

The application of mathematical models of economic stability, taking into account the dynamic structural standard, allows us to diagnose and monitor the development of a particular country and to predict its scenario in a short term for adaptation to various destabilizing factors of the internal and external environment.

REFERENCES

Anfylatov, V.S., Emelianov, A.A., Kukushkyn, A.A. (2003), *System analysis in management*, Finance and Statistics, Moskva (in Russian).

Arefieva, O.V., Horodynska, D.M. (2011), Managing economic sustainability of enterprises, European University, Kiev (in Ukraine).

Bachev, H. (2016), "Sustainability of farming enterprise – understanding, governance, evaluation", *Economics*, No. 2, pp. 6-15 (in Ukraine).

Borodkin, F.M., Aivazian, S.O. (2006), *Social indicators*, UNITY-DANA, Moskva (in Russian).

Borysov, V.V., Kruhlov, V.V., Fedulov, A.S. (2007), *Fuzzy models and networks*, Telecom, Moskva (in Russian).

Cheshnykov, C.V., Bocharnykov, V. P. (2007), *Fexcel program for working with fuzzy numbers in MSExcel version 4.0*, Consulting group "INEX2, Kiev (in Ukraine).

Danylenko, V.A. (2011), «Stability of the sub-industries of Ukraine in the conditions of the crisis». *Theoretical and applied issues of economics*, No. 24, pp. 322-329 (in Ukraine).

Halchynskyi, A. S. (2009), *Crises and cycles of world development*, ADEF-Ukraine, Kiev (in Ukraine).

Hassani, L., Daneshvarkakhki, M., Sabouhisabouni, M., Ghanbari, R. (2019), „The optimization of resilience and sustainability using mathematical programming models and metaheuristic algorithms", *Journal of Cleaner Production*, Vol. 228, pp. 1062-1072 (in USA).

Howarth, R. (2012), „Sustainability, well-being, and economic growth", *Minding Nature*, Vol. 5, No 2, pp. 32-39 (in USA).

Ivanov, V.L. (2010), «Ensuring organizational and economic stability of an industrial enterprise», *Collection of sciences. works of the East Ukraine National University named after Volodymyr Dahl*, Vol. 22, No. 1, pp. 31–39 (in Ukraine).

Kosianchuk, T. F., Liubchenko, N. L. (2011), *Comprehensive assessment of the economic stability of industrial enterprises*, KhNU, Kharkiv (in Ukraine).

Kozlovskyi, S.V. (2010), *Management of modern economic systems, their development and stability*, Merkiuri-Podillia,Vinnytsia (in Ukraine).

Lynnyk, O.I., Smolovyk, R.F., Yurieva, I.A. (2013), *Anti-crisis management at domestic and foreign enterprises: theory, diagnostics of the crisis situation, socio-economic aspects of management*, NTU "KhPI", Kharkiv (in Ukraine).

Malyarets, L.M., Smoliakova, O.M. (2014), „Determination of internal interconnections as conditions of economic stability of the enterprise", *Problems of the Eeconomy*, No. 4, pp. 455-465 (in Ukraine).

Marhasova, V.H. (2014), *System for ensuring the stability of the national economy and its security: theory, methodology, management practice*, Desna Polihraf, Chernigov (in Ukraine).

Melnyk, A.O. (2014), *World economic crisis: theory and methodology*, Institute of Agrarian Economics, Kiev (in Ukraine).

Miroshnichenko, T.S. (2011), „Basic concepts of sustainability of economic development", *Economic Bulletin Donbass*, No. 3, pp. 37-41 (in Ukraine).

Official site of the Ministry of Economic Development and Trade of Ukraine, available at: http://me.gov.ua (accessed: 22 May 2019).

Otenko, I.P., Malyarets, L.M., Ivashchenko, H.A. (2007), *Analysis and evaluation of the strategic potential of the enterprise*, KhNEU, Kharkiv (in Ukraine).

Payman, A., Searcy, C., Mohamad, Y., Jaber, A. (2018), „Quantitative Approach for Assessing Sustainability Performance of Corporations", *Ecological Economics*, Vol. 152, pp. 336-346 (in Netherlands).

Ponomarenko, T. V. (2016), *Estimation and formation of economic stability of the enterprise*, KNU, Kiev (in Ukraine).

Ponomarenko, V.C., Malyarets, L. M. (2009), *Analysis of data in researches of socio-economic systems*, INZHEK, Kharkiv (in Ukraine).

Ramazanov, S.K., Burbelo, O.A., Vitlinskyi, V.V. (2012), *Risks, security, crises and sustainable development in the economy. Methodologies, models, methods of management and decision-making*, NOULIDZh, Lugansk (in Ukraine).

Shandova, N.V. (2014), *Methodology and practice of management of sustainable development of industrial enterprises*, Book publishing house PE Vishymyrsky V.C., Kherson (in Ukraine).

Smulov, O.M. (2003), *Industrial and banking firms: interaction and crisis resolution*, Finance and Statistics, Moskva (in Russian).

Stockhammer, E., Hochreiter, H., Obermayr, B., Steiner, K. (1997), „The index of sustainable economic welfare (ISEW) as an alternative to GDP in measuring economic welfare. The results of the Austrian (revised) ISEW calculation 1955–1992", *Ecological Economics*, Vol. 21, No 1, pp. 19-34 (in Netherlands).

Suroezhyn, I. M. (1970), *Essays on the Theory of Industrial Organizations: Scientific Edition*, Ekonomyka, Moskva (in Russian).

Synytsia, L. V. (2010), *Estimation of enterprise sustainability*, Volodymyr Dahl East Ukraine National University, Lugansk (in Ukraine).

Trianni, A., Cagno, E., Neri, A., Howard, M. (2019), "Measuring industrial sustainability performance: Empirical evidence from Italian and German manufacturing small and medium enterprises", *Journal of Cleaner Production*, Vol. 229 pp. 1355-1376 (in USA).

Yarushkyna, N. H. (2004), *Fundamentals of the theory of fuzzy and hybrid systems*, Finance and Statistics, Moskva (in Russian).