ESTIMATION OF THE INFLUENCE OF "SHOCKS" ON THE DYNAMICS OF INDICATORS OF MACROREGIONAL FINANCIAL SECURITY

***Tamara Klebanova*[1], *Lidiya Guryanova*[2], *Vitalii Gvozdytskyi*[3]**

[1]*Doctor of Science in Economics (Habilitation in Economics), professor, Head of the Department of economic cybernetics, Simon Kuznets Kharkov National University of Economics, Ukraine, Kharkiv, 61166, Nauky ave., 9a* E-mail: t_kleb@ukr.net, Tel: +38-067-7646958; Fax: +38-057-7020717

[2]*Doctor of Science in Economics (Habilitation in Economics), associate professor, Professor of the Department of economic cybernetics, Simon Kuznets Kharkov National University of Economics, Ukraine, Kharkiv, 61166, Nauky ave., 9a* E-mail:guryanovalidiya@gmail.com, Tel: +38-067-9909704; Fax: +38-057-7020717

[3] *Candidate of Science in Economics (Phd), lecturer of the Department of economic cybernetics, Simon Kuznets Kharkov National University of Economics, Ukraine, Kharkiv, 61166, Nauky ave., 9a* E-mail: gvozdikramm@gmail.com, Tel: +38-097-133-78-77; Fax: +38-057-7020717

Abstract: A methodical approach to the formation of a set of models of the predictive-analytical mechanism of the system of ensuring the financial security of macroregions is proposed. The methodical approach is based on the synthesis of canonical correlation methods, factor analysis, taxonomy methods, vector autoregressive technologies and error correction models. Models have been developed to evaluate the dynamic effects of the influence of "shocks" on the financial security of macroregions. The stability of the system is assessed on the example of the given countries of the European Union and Ukraine; security subsystems that are most sensitive to the impact of external "shocks" and priority channels for the transmission of external stresses / infections are identified.

Keywords: macroregion, financial security, assessment of the impact of the "shocks", multidimensional analysis, econometric modelling

Introduction

Modern conditions for the functioning of economic systems require the development of qualitatively new mechanisms for ensuring the financial security of macroregions (countries). This is explained by the fact that, along with a number of positive synergetic effects, various forms of integration inherent in the modern stage of economic development carry global risks and threats. Such risks, in particular, include an unidirectional reaction to "shocks" and the effect of the "epidemic," the depreciation of assets in partner countries, the deterioration of trade conditions. The development of a model basis of the mechanism of monitoring such specific risks and threats, which allows to assess the impact of the "shocks" on the stability of the system of financial security of the macroregion (SFSM) as a whole is one of the basic directions for its improvement.

It should be noted that the problem of developing a model basis of the system of financial security of macroregions is widely sanctified in the economic literature. Thus, the work of A. Chernyak and V. Khomyak [1] is devoted to the modelling of currency security as a dominant component of the FSM, to the forecasting the balance of payments crisis, and to the selection of mechanisms for its prevention. In the studies of K. Kovalchuk, S. Marinchuk [2], the problem of developing a model basis for selecting offshore zones for tax optimization is considered, and the task of forming effective "internal" tax loyalty zones is touched upon. The paper of G. Velikoivanenko, I. Miroshnichenko touches on the issues of modelling investment potential, the level of investment security of the macroregion [3]. Various aspects of modeling the financial and economic security of the macroregion were considered in the works of T. Klebanova, L. Gurianova, L. Chagovets [4-6]. It should be noted that, despite the unconditional effectiveness of the approaches proposed by the authors, the existing developments concern local assessment tasks, forecasting the level of financial security, assessing the level of threats, the consequences of their prolonged impact. The problem of implementation of the system approach, which allows analyzing the interrelationship of the main elements of the financial security system, is poorly touched; identifying components that, at certain stages, contribute to an increase in the overall level of financial security, or, on the contrary, create additional threats under the influence of external "shocks".

Data and methods of research

The paper suggests a methodical approach to the formation of a model basis of predictive-analytical mechanism of SFSM, which, based on the methods of factor analysis, canonical correlations, the development level method, VAR-, ECM-models, allows assessing the dynamic effects of the influence of external "shocks" (threats) on functional components and the system as a whole; evaluating the stability of the system.

The proposed methodical approach is shown in Fig. 1 and includes the following main blocks: 1) the formation of a system of diagnostic indicators of the financial security of the macroregion; 2) an integrated assessment of the level of financial security of the macroregion; 3) the formation and analysis of scenarios of impulse responses of indicators of financial security of the macroregion to the impact of external "shocks".

In block 1, a system of diagnostic indicators of the financial security of the macroregion is formed. Preliminary list of indicators is developed on the basis of expert analysis methods. The procedure of expert analysis is described in more detail in [7]. To assess the informativenessand filter the formed list of indicators, various methods can be used: methods based on the criteria of autoinformativeness; methods aimed at assessing the informativeness based on the analysis of cause-effect relationships. The first group of methods makes it possible to evaluate the information significance of the indicators, to reveal

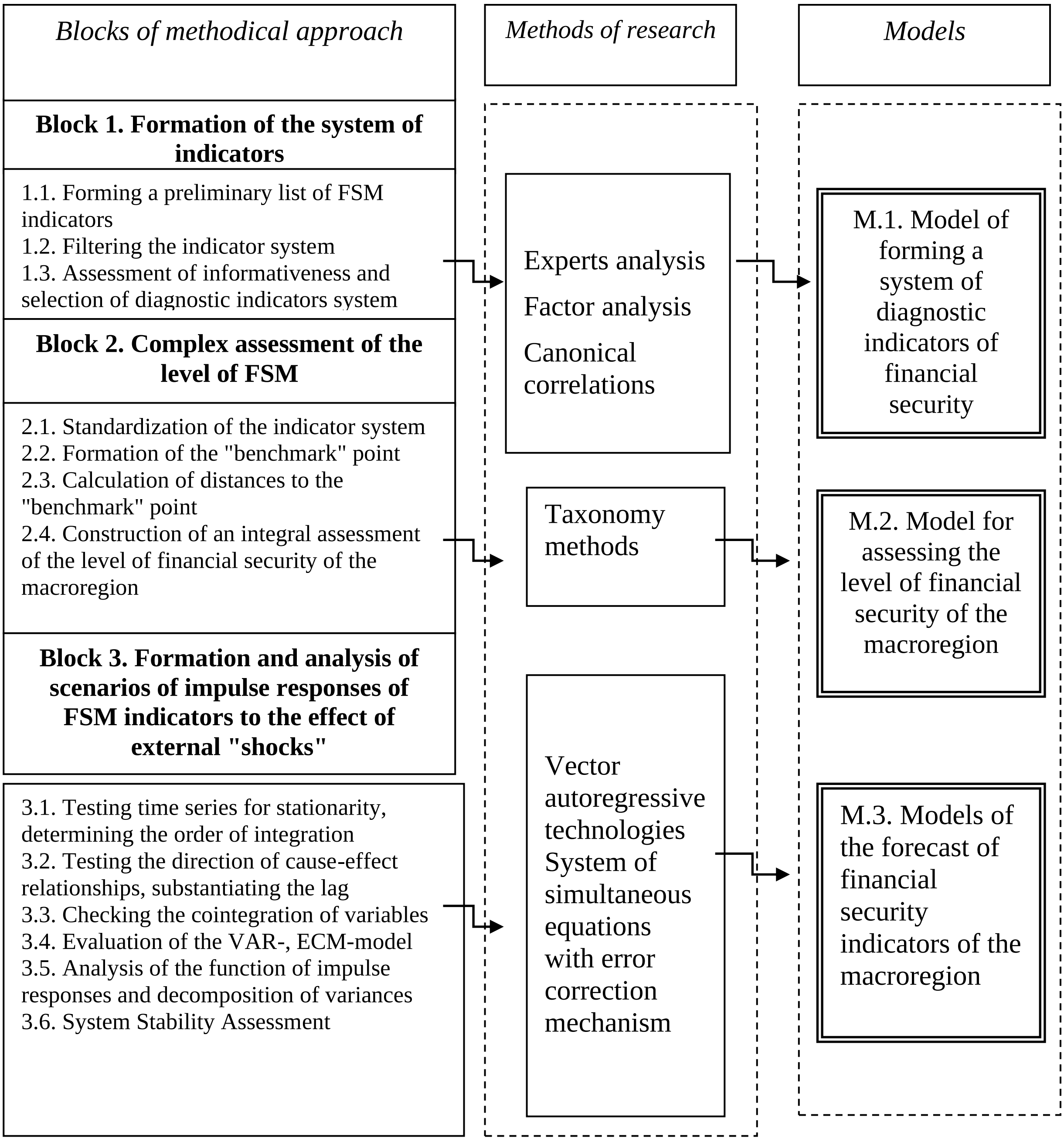

Fig. 1. Scheme of the interrelation of the main blocks of the methodical approach to the formation of a model basis of predictive- analytical mechanism of the SFSM

hidden properties and patterns in large volumes of raw data, in thecase when the structure of the input and output data sets is unknown. The advantage of the second group of methods is the possibility of reducing the dimensionality of the information space of features on the basis of analysis of the cause-effect relationships of a set of input and output indicators. The choice of the method is determined by full or incomplete provision of information, initial data size, the structure of a set of input and output indicators, and the availability of a training data. Taking into account the limitations on the data type, the structure of the indicator groups, a block diagram of the filter of the system of financial security indicators is developed, a detailed description of which is given in [6, 8]. The proposed approach is based on techniques of canonical analysis and principal components.

Principal components f_i are linear orthogonal combinations of initial indicators of financial security of a macroregion: $f_i = \sum_{j=1}^{m} b_{ij} x_j$, $\sum_{j=1}^{m} b_{ij}^2 = 1$, $\sum_{i=1}^{m} b_{ij} b_{ik} = C$, $j \neq k$. Formation of the system of principal components is reduced to a step-by-step transformation of the matrix of input data, which can be represented as follows: $X \to R \to \lambda, U \to V \to A \to F$, where X - initial data matrix, R - matrix of pair correlations, - eigenvalues and the matrix of eigenvectors, V - matrix of normalized values of eigenvectors, A - matrix of factor mapping, F - matrix of principal components. Analysis of the elements of the matrix of the factor mapping A =(a_{jr}) is the basis for constructing the following subsets: φ_1 - subset of insignificant indicators; φ_2 - subset of significant indicators; φ_3 - subset of significant indicators that are not involved in the formation of the principal components; φ_4 - subset of significant parameters involved in the formation of the principal components. The first level of the filter of the initial system of financial security indicators is based on the allocation of a subset φ_4, which is considered informative if the following condition is satisfied: $K_r = \frac{\sum_{j=1}^{n} a_{jr}^2 \{\varphi_2 - \varphi_3\}}{\sum_{j=1}^{n} a_{jr}^2} \geq 0,75$, $r = \overline{1,k}$. Thus, the choice of the main component method is explained by the possibility of forming a system of generalized latent factors, determining the most informative indicators.

The second level of the filter is based on the analysis of the interrelation between the indicators of financial and economic security of the macroregion (as a subsystem of a higher level) by the method of canonical correlations. The canonical correlation is the correlation between canonical variables $U = \sum_{j=1}^{m_1} a_j x_j$ and $V = \sum_{j=1}^{m_2} b_j y_j$. Formation of the system of canonical variables can be represented by the following scheme: $X_3, X_4 \to R_{33}, R_{34}, R_{43}, R_{44} \to C \to \lambda, B \to A$, where X_3, X_4 - initial data matrices of dimension nm_1 and nm_2, $R_{33}, R_{34}, R_{43}, R_{44}$ - matrices of pair correlations, C - product matrix $C = R_{44}^{-1} R_{43} R_{33}^{-1} R_{34}$, λ, B - eigenvalues and the eigenvector matrix, A - matrix of coefficients for factor variables in the system of canonical correlations.

The matrix of pair correlations is divided into four parts: $R=\begin{pmatrix} R_{33} & R_{34} \\ R_{43} & R_{44} \end{pmatrix}$. Based on this, auxiliary matrices $R_{44}^{-1}, R_{33}^{-1}, C = R_{44}^{-1}R_{43}R_{33}^{-1}R_{34}$ are determined. Next, the eigenvalues of the matrix C and the corresponding basis of eigenvectors B_1, $B_2,\ldots,B_p$. Coefficients for factor variables in the system of canonical correlations are calculated by the formula: $A_i = \frac{R_{33}^{-1}R_{34}B_j}{\lambda_j}$. If to rank eigenvalues $\lambda_1 \geq \lambda_2 \geq . . . \geq \lambda_\pi$ in descending order, then λ_1^2 will correspond to the maximum canonical correlation coefficient.

In the process of canonical analysis, the initial data are reduced to a standardized form, therefore the coefficients in the expressions for canonical variables characterize the force of the influence of the corresponding initial indices, which makes it possible to obtain their ranked sequences. Screening of nonessential indicators is carried out on the basis of a multi-step procedure, in which at each step only one variable is discarded, the least significant in this sequence. To compare the canonical correlations of the original r_k and r_{k+1} set of factors Fisher z -transformation is used.

Thus, the method of canonical correlations makes it possible to analyze the relationship between several output indicators and a large number of factors. This property is important in justifying the indicators in the safety management system, since the dynamics of the subsystems of financial and economic security are characterized by a large set of characteristics. The choice of one most significant indicator will lead to a distortion of the results of the assessment.

In ***block 2***, a comprehensive assessment of the level of financial security and its structural components is carried out. The construction of a system of integrated (on the whole system of indicators) and local (on separate components) integral estimates of the level of financial security is caused by the diversity of indicators, which complicates their analysis and requires presentation in the form of a synthetic assessment, which is the result of a convolution of indicators reflecting the development of individual financial security subsystems. The block diagram of the formation of an integrated assessment of the level of financial security is based on one of the methods for constructing a reference object - on taxonomic indicator of the level of development [7]. The indicator of the level of development is calculated by the formula: $d_i^* = 1 - \frac{c_{i0}}{c_0}$, where $c_o = \overline{c_0} + 2S_0$, $\overline{c_0} = \frac{1}{n}\sum_{i=1}^{n} c_{io}$,

$S_o = \frac{1}{n}\sqrt{\sum_{i=1}^{n}(c_{i0} - \overline{c_0})^2}$, $c_{io} = \sqrt{\sum_{j=1}^{m}\left(Z_{ij} - Z_{oj}\right)^2}$ - The Euclidean distance between the points-units (states) and the point *P0* ($z_{01}, z_{02}, ..., z_{0m}$), which is a development benchmark. The basis for constructing a developmental standard is the division of characteristics into stimulants and destimulators. The signs that have a positive, stimulating effect on the level of financial security are called stimulants, in contrast to the signs-destimulators. The coordinates of the development benchmark are defined as follows: $z_{0j} = \begin{cases} \max_i z_{ij}, if \ \ j \in I \\ \min_i z_{ij}, if \ \ j \notin I \end{cases}$, where I - a set of stimulants. Since the signs have different dimensions, when forming the distance matrix $C = (d_{io}), i = \overline{1,n}$ their standardization is carried out: $z_{ij} = \frac{x_{ij} - \overline{x_j}}{S_j}$, $S_j = \sqrt{\frac{\sum_{i=1}^{n}\left(x_{ij} - \overline{x}_j\right)^2}{n-1}}$. The values of the integral change in the range from 0 to 1. The closer the values of the integral indicator to 1, the higher the level of financial security of the macroregion.

In ***block 3***, an analysis of the impulse responses of the FSM indicators to the effect of external "shocks" is carried out. To solve this problem, *VAR*- and *ECM*-models are used. The choice of this tool is caused by the ability to model interrelated financial variables; investigate the long-term relationship and deviations from the equilibrium state; assess the impact of "shocks" on the dynamics of financial security indicators. Conducting the cointegration analysis involves: checking time series for stationarity using the Dickey-Fuller criterion; definition of the order of integration; verification for cointegration; the construction of *ECM* or *VAR* model; impulse analysis and decomposition of dispersions. Pulse analysis (analysis of response to "shocks") allows dynamic imitation of an external "shock" with respect to each of the endogenous variables, and then evaluate the response of the system to this impulse. The function of impulse responses shows the change in endogenous indicators in response to a "shock" (a change in one of the perturbations of the system). The decomposition of variances in forecast errors makes it possible to analyze the effect of different shocks on the variance of the forecast error for different anticipation periods. In other words, the decomposition of variances shows the proportions of the variance caused by the "shocks" of the various variables. A more detailed description of the flowchart for analyzing the dynamics of financial indicators using VAR and ECM-models is given in [9].

The methodological approach which is proposed above is implemented on the data of financial security indicators of the countries of the European Union and Ukraine for the last eight years in a monthly section. The choice of the analysis period is caused by the methodological continuity and information security of the system of financial security indicators. The calculations were carried out with the help of software packages "Statistica", "EViews". Below is a description of the main results.

Results of the research

The implementation of the first two blocks of the above methodical approach has made it possible to obtain a system of integrated indicators of the level of financial security of the countries of the European Union and Ukraine. Dynamics of the generalized (throughout the system indicators) and local (for individual components - budget security, money market security, currency security, debt security, insurance market security, stock market security, banking system security, investment security) of the integrated indicators of financial security of the EU countries is given in Fig. 2.

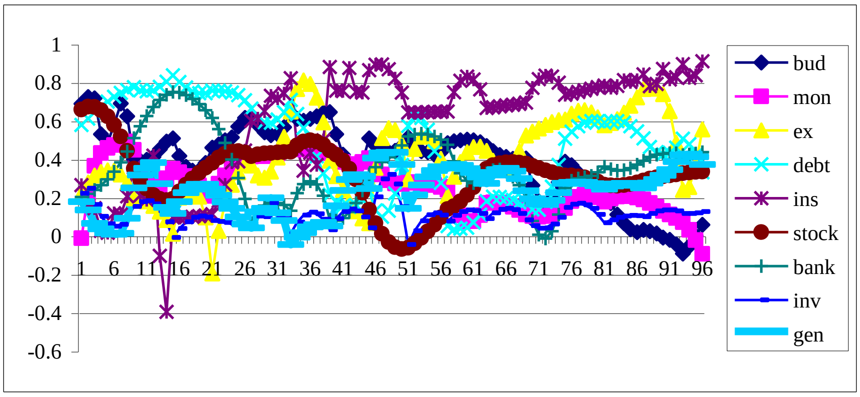

Fig. 2. Dynamics of integral indicators of financial security of the Eurozone countries*

*Legend: bud - budget security, mon - money market security, ex - currency security, debt - debt security, ins - insurance market, security stock - stock market security, bank - banking system security, inv - investment security, gen - financial security.

Analysis of the data shown in Fig. 2, allows us to conclude that there are stable positive trends in the level of insurance, banking, stock and investment security of the Eurozone countries. Negative trends are characteristic for foreign exchange, debt, monetary, and budgetary security. For the level of financial security in general, there is a positive dynamics of change. However, the value of the integral indicator of the level of financial security at the end of the analyzed period, equal to 0.38, indicates a significant level of threats.

To analyze the impact of "shocks" on the dynamics of financial security indicators of the EU countries, a vector autoregressive model was constructed (block 3 of the methodical approach). The testing of time series for stationarity was carried out using the ADF test. The test results showed that the time series of integral indicators of banking, debt, currency, investment security are stationary in levels. For the other indicators, the first differences were made. An analysis of the orientation of the cause-effect relationships of 36 pairs of variables was carried out on the basis of the Granger test. The obtained data confirm the hypothesis about the existence of bilateral causal relations between the level of stock and debt security, currency and financial security, stock and insurance security, etc. with a probability of 99%. The lag value during the test implementation and the construction of the vector autoregressive model was determined on the basis of the Akayka information criterion. The minimum value of the criterion is characteristic for lag 7. This lag was given exogenously when estimating the vector autoregressive model. Since the variables have different integration order, the cointegration test was not performed. The estimation of VAR (7) was carried out in "*EViews*". Some of the equations of the resulting complex model are given below.

For financial security (D_GEN):

D_GEN = 0.828830916*BANK(-1) - 0.4949309999*BANK(-2) + 0.6163032878*BANK(-3) - 0.4959966306*BANK(-4) + 0.1238740563*BANK(-5) - 0.4581045501*BANK(-6) + 0.3478035397*BANK(-7) + 0.06982694966*D_BUD(-1) - 0.009389585477*D_BUD(-2) + 0.1789320321*D_BUD(-3) + 0.03880322057*D_BUD(-4) + 0.3822356991*D_BUD(-5) + 0.2169918401*D_BUD(-6) + 0.5515576804*D_BUD(-7) - 0.4491506326*D_GEN(-1) - 1.290992056*D_GEN(-2) - 0.7338805126*D_GEN(-3) - 0.9506326885*D_GEN(-4) - 0.8234106079*D_GEN(-5) + 0.1522253069*D_GEN(-6) + 0.01993907634*D_GEN(-7) - 0.2122732786*D_INS(-1) + 0.008270123541*D_INS(-2) + 0.02457243337*D_INS(-3) + 0.3134131417*D_INS(-4) + 0.2055922162*D_INS(-5) + 0.1086711083*D_INS(-6) - 0.08185344372*D_INS(-7) + 0.3131143912*D_MON(-1) - 0.01988561981*D_MON(-2) + 0.2523320897*D_MON(-3) + 0.210542013*D_MON(-4) + 0.4532461548*D_MON(-5) - 0.5489996439*D_MON(-6) + 0.613789663*D_MON(-7) - 0.4729456303*D_STOCK(-1) - 1.017422795*D_STOCK(-2) - 0.9213785578*D_STOCK(-3) - 1.057521494*D_STOCK(-4) + 0.1515028706*D_STOCK(-5) + 2.557572904*D_STOCK(-6) - 2.045967121*D_STOCK(-7) - 0.3909217662*DEBT(-1) + 0.2261572368*DEBT(-2) - 0.1803190113*DEBT(-3) + 0.1026238434*DEBT(-4) + 0.1137516062*DEBT(-5) - 0.3700444109*DEBT(-6) + 0.2670845323*DEBT(-7) - 0.1754552583*EX(-1) + 0.0335588931*EX(-2) + 0.07190442738*EX(-3) + 0.1442004369*EX(-4) + 0.3470098191*EX(-5) - 0.1935683917*EX(-6) + 0.054707558*EX(-7) + 0.161902259*INV(-1) - 0.9792083161*INV(-2) - 0.09053245336*INV(-3) - 0.181617282*INV(-4) - 1.261408638*INV(-5) + 0.2754656634*INV(-6) + 0.05592434848*INV(-7) + 0.06460795795.

For insurance security (D_INS):

D_INS = 0.3692602274*BANK(-1) + 1.078509608*BANK(-2) - 1.652694885*BANK(-3) + 0.9434502178*BANK(-4) - 1.734381029*BANK(-5) + 2.548838306*BANK(-6) - 0.9211097404*BANK(-7) - 0.1371349985*D_BUD(-1) + 0.4993099653*D_BUD(-2) - 0.4392261089*D_BUD(-3) + 0.5984668814*D_BUD(-4) + 0.4877719619*D_BUD(-5) + 0.8332769235*D_BUD(-6) - 0.02144763941*D_BUD(-7) - 0.9444999312*D_GEN(-1) - 1.908416621*D_GEN(-2) - 2.462445191*D_GEN(-3) - 0.1495725597*D_GEN(-4) - 1.073723615*D_GEN(-5) + 0.02510428871*D_GEN(-6) - 1.327231771*D_GEN(-7) - 0.3516108604*D_INS(-1) - 0.4895901819*D_INS(-2) + 0.331842255*D_INS(-3) - 0.3341096262*D_INS(-4) + 0.07684849449*D_INS(-5) - 0.3380823111*D_INS(-6) + 0.3140812943*D_INS(-7) - 0.4384829896*D_MON(-1) + 0.387045979*D_MON(-2) + 0.7637392641*D_MON(-3) + 0.2875392037*D_MON(-4) - 1.029677015*D_MON(-5) + 1.246476691*D_MON(-6) + 0.046194034*D_MON(-7) - 0.7090356163*D_STOCK(-1) - 1.422503666*D_STOCK(-2) - 4.011831304*D_STOCK(-3) + 1.752337225*D_STOCK(-4) + 3.780686448*D_STOCK(-5) - 3.710155779*D_STOCK(-6) + 0.2853239515*D_STOCK(-7) - 0.3641975229*DEBT(-1) - 0.1666058503*DEBT(-2) + 0.4875136058*DEBT(-3) - 0.3528610617*DEBT(-4) + 0.4434867169*DEBT(-5) - 0.3294806204*DEBT(-6) + 0.05682052619*DEBT(-7) - 0.4239914223*EX(-1) - 0.0896506412*EX(-2) + 0.368782965*EX(-3) + 0.2405763069*EX(-4) - 0.1517298806*EX(-5) + 0.2776503936*EX(-6) + 0.08732887771*EX(-7) + 0.9410319866*INV(-1) + 0.4152263496*INV(-2) - 2.581235778*INV(-3) + 0.3614957699*INV(-4) - 0.814152898*INV(-5) + 0.6734041314*INV(-6) - 1.081142743*INV(-7) + 0.03006966448

The quality criteria for the forecast of financial security indicators obtained on the basis of VAR (7) are presented in Table. 3.

Table 3

Quality criteria of the VAR model equations (p=7)

Legend	BANK	BUD	D_DEBT	D_EX	GEN	INV	INS	MON	STOCK
R-squared	0.995736	0.721364	0.912823	0.900171	0.940949	0.976900	0.994306	0.987824	0.985268
m.e.	-0,00148	0,000857	0,000539	0,000703	0,000547	-0,00089	0,000854	0,0003754	0,0014424
m.a.e.	0,03342266	0,01521557	0,01834	0,015133	0,099421	0,008151	0,009854	0,005536	0,037331
m.a.p.e.	9,213914	6,978623	7,954685	6,397851	16,62604	2,044886	3,584264	4,899595	2,405671

The mean absolute error of approximation for time series of integral indicators of budget, monetary, currency, debt, equity, banking, investment, financial security does not exceed 10%. This allows us to draw a conclusion about the high quality of the model and the possibility of its application for further research. The results of the analysis of the impulse response function are given in Fig. 3.

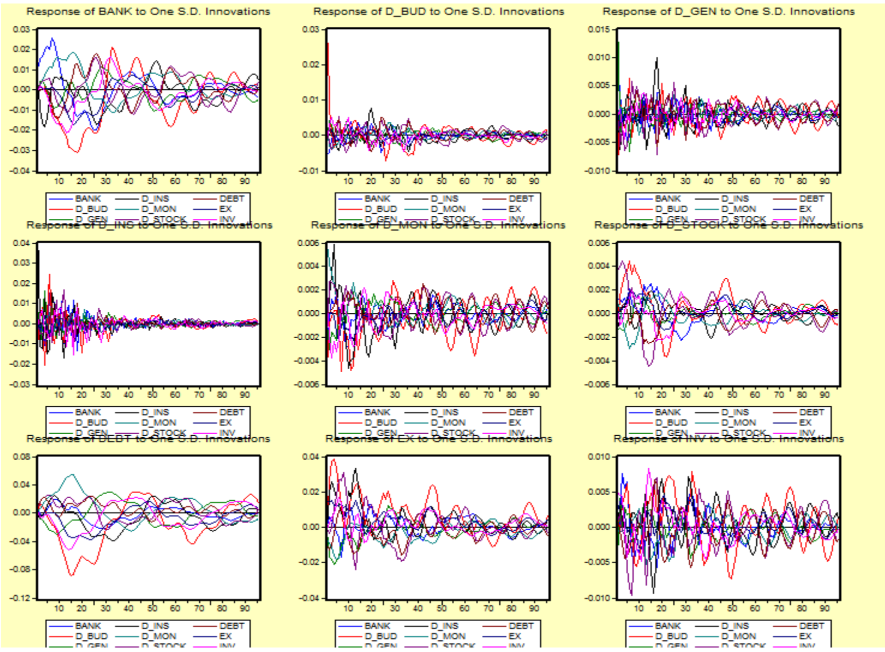

Fig. 3. Functions of impulse responses of integral indicators of financial security of the EU countries

Analysis of the data makes it possible to conclude that the system is dynamically stable. In the medium term, the impact of "shocks" is eliminated. At the same time, there is a high probability of occurrence of short-term local crises, since the reaction at the time of the impact of "shock" often has the character of "explosive" fluctuations.

The analysis of decomposition of dispersions allowed to draw a conclusion about the first importance of threats to the security of the stock market as a channel for transferring external financial stresses / infections. This is indicated by the number of unbalanced areas of financial security after the impact of local "shocks" of stock security.

A similar analysis was made on the data of financial security indicators of Ukraine. The VAR (8) model was developed, the study of which showed that the system is not dynamically stable, the "shocks" of currency security lead to significant fluctuations in practically all the subsystems of the FSM. The absence of an effective financial policy will lead to the entry of the system into a bifurcation point in five years. But if to level out the "shocks" of currency security, the situation stabilizes.

Conclusion

Thus, models for the analysis of financial security indicators for dynamically stable systems have been developed that have shown that under current conditions there is a high probability of forming short-term local crises, since the reaction at the time of the impact of "shock" often has the character of "explosive" fluctuations. The research of the models of a dynamically unstable system made it possible to determine the points of bifurcation, the dominant threats, the elimination of which makes it possible to stabilize the situation. Security subsystems, which are most sensitive to the influence of external "shocks", priority channels for the transmission of external stresses / infections identified. The developed set of models can be considered as an element of the model basis of forecasting and analytical mechanism of the system of financial security of the macroregion.

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