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The simulation modeling of the EAEU development scenarios under the influence of various economic factors

El modelado de simulación de los escenarios de desarrollo de EAEU bajo la influencia de varios factores económicos

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Contents

ABSTRACT:
The article considers the current use of economic and mathematical modeling in managing the development of the Eurasian Economic Union (EAEU) and coordinating the interaction among participating countries. The authors make suggestions for the development and deepening of the available tools in this area using original game-theoretic macroeconomic models, which provide an integral and interconnected description of socio-economic development of states and their associations, and other applied mathematical models. The study examines an autarkic single-product operating game model making it possible to estimate the expected GDP, qualification levels, education, and health of the population; the state of natural resources and total assets of states and their associations for various distribution options of the created product among consumption spending, R & D, modernization of production, education, healthcare, nature protection, security, and public administration. The authors describe the original optimality principles and the approaches to assessing the security of countries, regions, and territories that can be used to achieve the desired objective. The article suggests a methodology for simulation of development scenarios of the EAEU (and its member states), based on the use of tools considered in the study. The authors formulate the requirements for initial data required for such simulation.
Keywords: simulation, operations research, EAEU,

RESUMEN:
El artículo considera el uso actual de modelos económicos y matemáticos en la gestión del desarrollo de la Unión Económica Euroasiática (EAEU) y la coordinación de la interacción entre los países participantes. Los autores hacen sugerencias para el desarrollo y la profundización de las herramientas disponibles en esta área utilizando modelos macroeconómicos originales de teoría de juegos, que proporcionan una descripción integral e interconectada del desarrollo socioeconómico de los estados y sus asociaciones, y otros modelos matemáticos aplicados. El estudio examina un modelo de juego operativo de un solo producto autárquico que permite estimar el PIB esperado, los niveles de calificación, la educación y la salud de la población; El estado de los recursos naturales y los activos totales de los estados y sus asociaciones para diversas opciones de distribución del producto creado entre gasto de consumo, I + D, modernización de la producción, educación, salud, protección de la naturaleza, seguridad y administración pública. Los autores describen los principios originales de optimización y los enfoques para evaluar la seguridad de los países, regiones y territorios que se pueden utilizar para lograr el objetivo deseado. El artículo sugiere una metodología para la simulación de escenarios de desarrollo de la EAEU (y sus estados miembros), basada en el uso de herramientas consideradas en el estudio. Los autores formulan los requisitos para los datos iniciales requeridos para tal

scenario modeling, game-theoretic models, socio-economic development

simulación.
Palabras clave: simulación, investigación operativa, EAEU, modelado de escenarios, modelos de teoría de juegos, desarrollo socioeconómico

1. Introduction

The Eurasian Development Bank (EDB) and the Eurasian Economic Commission (EEC) inextricably linked with the EAEU have made notable efforts in forecasting and modeling since 2013; this has resulted in the Integrated Model System (IMS), which is a software package including:

interconnected macroeconomic models of economic development of the EAEU countries;

software environment, making it possible to form standard reports by economic sectors and effectively use models to analyze and forecast policy measures;

dynamically updated database.

The IMS system of analysis and forecasting allows making quantitative estimates of various development scenarios for the EAEU in general and its member countries and assessing the risks associated with changes in commodity prices and other macroeconomic indicators; it also helps to draft recommendations for coordinating the macroeconomic policies of the EAEU member states.

The IMS involves models with monetary and fiscal sectors. The use of such models is accompanied by the processing of expert assessments of forecasters. The forecasts are made for a period of 1 to 4 years.

The work performed within the framework of the IMS allows considering the next stage of using mathematical modeling in managing the EAEU development – the creation and implementation of holistic and interrelated mathematical models of the EAEU functioning, which allows supporting the adoption of the full range of management decisions for this union of states. The most advanced and developed precise language suitable for solving such problems is the language of mathematical game theory, the basic concepts of which were presented in (Neumann, & Morgenstern, 1970). The initial stage of game theory development is associated with the analysis of parlor games and the consideration of antagonistic games (zero-sum games). Consideration of games with non-opposing interests (non-antagonistic games) corresponding to the realities of production-economic and socio-economic (micro- and macroeconomic) interactions is associated with the name of Germeyer (1976). In his last fundamental work, Germeyer proposed a synthesis class of game models (games with a hierarchical vector of interests), considering a hierarchical system of coalitions of zero-level players, coalitions of such coalitions, etc. (Germeyer, & Vatel, 1974). Apart from selfish interests, zero-level players go after the interests of all coalitions in which they participate (directly or recurrently). Therefore, the winning function of each zero-level player is a certain convolution of the winning functions of such coalitions. For the subclass of games in which zero-level players divide their limited resources and consider only certain convolution as a minimum, there is an algorithm for determining the existence of strong Nash equilibria.

The theory of games with non-opposing interests has developed significantly in numerous works by representatives of Germeyer's school. In particular, the process of practical decision-making and production-and-economic forecasting (Federal Target Program "Reform and Development of the Defense-Industrial Complex in 2002-2006", development of industrial policy of the Moscow Government in 2007-2009, the General Plan of Development and Location of the Moscow Industry in 2008-2020, the simulation module of the Situation Center of the State Automated System of the State Defense Order (SC SAS SDO)) resulted in a methodology of operating game scenario modeling, tested in solving several micro- and macroeconomic challenges (Kononenko, & Shevchenko, 2013; Ereshko, & Shevchenko, 2014). This methodology has resulted in the establishment of the autarkic single-product game model (of a degenerate type "game with nature") of distribution of the produced product among the costs of consumption, R & D, production modernization, education, healthcare, nature protection, security, and public administration in order to maximize one or another indicator (Kononenko, & Shevchenko, 2013; Chursin et al., 2019; Ukolov et al., 2019). At the first stage of holistic and interconnected precise description and simulation of socio-economic processes in the EAEU, it seems reasonable to use this simple operating game model. When conducting multicriteria assessments, the authors suggest building the Pareto set and using it to optimize one or another integral functionality of the common interests of the entire set of participants in the game process, of one or the other criteria set. Some authors suggest using the security criterion of a region as one of the criteria for

assessing the quality of a development scenario of the EAEU in general or its participant countries (Shumov, 2016; Kokuytseva, 2019; Rodionova, & Kokuytseva, 2018; Kokuytseva, & Ostrovskaya, 2014; Mikhaylov et al., 2018; Zeibote et al., 2019; Pavolová et al., 2019).

2. Materials and Methods

Kononenko & Shevchenko (2013) published an autarkic single-product operating game model (or, considering the uncertainties, a two-player "game with nature" type), in which a state (region, union of states) implements production, innovation-modernization, educational, health, environmental, training, consumer, demographic and R & D operation to create IA (intangible assets). The costs of security and public administration in the first version of this model are counted as components of the required consumption, the size of which might vary. The process is considered in discrete time. Product storage is not provided.

Of all the accounts, the model considers active accounts of fixed assets and the product, passive profit account balancing active accounts, off-balance accounts of natural resources, along with the number, qualification level, and potential, healthcare and enlightenment (common culture) of human resources. A player’s performance criterion has the form (ecustion 1) with the averaged value of the third component.

$$F(t) = PA(t) + NR(t) + \\ + \theta_0 \cdot \sum_{j=1}^{q} ql_j(t) \cdot hl_j(t) \cdot 2^{\nu(cl_j(t)-cl_0)} \quad (1)$$

where:

$F(t)$ is the value of the player's performance criterion at the moment of time *t* of the operating game interaction;

$PA(t)$ is the value of the player's net assets at the moment of time *t* of the operational game interaction;

$NR(t)$ is the valuation of natural resources at the player's disposal at the moment of time *t*;

q is the player's (country's) population;

$ql_j(t) \geq 0$ is the qualification level of the *j*-th human resources representative at the moment of time *t*;

$hl_j(t) \geq 0$ is the level of health of the *j*-th human resources representative at the moment of time *t*;

$cl_j(t)$ is the level of enlightenment of the *j*-th human resources representative at the moment of time *t*, specified as a number from 0 to 100;

cl_0 is the number in the range from 0 to 100, which determines the reference level of enlightenment (general culture, spiritual and moral development, wisdom) of an individual;

ν is the parameter determining the degree of the exponential growth of economic importance (value) of a person with an increase in his or her level of enlightenment;

θ_0 is the valuation of economic significance (value) of a person with reference (individual) levels of health and qualifications and with a level of enlightenment (general culture, spiritual and moral development, and wisdom) cl_0.

The procedures used by the United Nations (UN) and other generally recognized international institutions can be used to obtain cost estimates of natural and human resources as a first approximation.

Estimates of the θ_0, ν, cl_0, and $cl_{ij}(t)$ values (relating to the subtle characteristics of an individual, his or her level of wisdom (enlightenment) and its cost) can be considered significantly more complex, but not impossible.

For this operating game, the dynamics equations of the process under discussion, without considering the influence of uncertain factors, are written as:

$$pr(t) = \min\left(\frac{f(t)}{fe(t)}, \frac{qvp(t)}{te(t)}\right) = \\ = uf(t) + up(t) + unr(t) + uqv(t) + uh(t) + uc(t) + us(t) + uin(t)$$

$$qvp(t) = q(t) \cdot QL(t) = qvp(t-1) + eqv(t-1) \cdot uqv(t-1)$$

$$f(t) = f(t-1) \cdot (1 - kvf) + ef(t-1) \cdot uf(t-1)$$

$$q(t) = q(t-1) \cdot (1 - \%_{mort}) + \frac{1}{p_{\min}} (up(t) - (p_{\min} + p_{pub}) \cdot q(t-1))$$

$$HL(t) = HL(t-1) + \frac{1}{q(t-1)} eh(t) \cdot uh(t)$$

$$CL(t) = CL(t-1) + \frac{1}{q(t-1)} ec(t) \cdot uc(t)$$

$$NR(t) = NR(t-1) - (zm(t-1) \cdot me(t-1) + ecol(t-1)) \cdot pr(t-1) + \\ + enr(t-1) \cdot unr(t-1)$$

$$nma(t) = nma(t-1) + es(t-1) \cdot us(t-1)$$

$$fe(t) = fe(t-1) - e\inf(nma(t-1)) \cdot uin(t-1)$$

$$te(t) = te(t-1) - e\inf(nma(t-1)) \cdot uin(t-1)$$
$$me(t) = me(t-1) - einm(nma(t-1)) \cdot uin(t-1) \quad (2)$$
$$ecol(t) = ecol(t-1) - einec(nma(t-1)) \cdot uin(t-1)$$
$$F(t) = PA(t) + NR(t) +$$
$$+ \theta_0 \cdot q(t) \cdot QL(t) \cdot HL(t) \cdot 2^{\nu(CL(t)-cl_0)}$$ where:
$$PA(t) = PA(t-1) + f(t) - f(t-1)$$

$pr(t), f(t)$ are the volume of product output and the value of fixed assets at the moment of time *t*;

$fe(t), te(t), me(t), ecol(t)$ refer to capital intensity, labor intensity, material-energy intensity and non-ecological compatibility (damage to natural resources in the production of a unit production) of a production operation at the moment of time *t*;

$uf(t), up(t), unr(t), uqv(t), uh(t), uc(t), us(t), uin(t)$ refer to the product expenditures for fixed assets, consumption, environmental protection, human resources development, healthcare, education, science (R&D), innovation and modernization operations at the moment of time *t*;

$QL(t) = \frac{1}{q(t)} \sum_{j=1}^{q(t)} ql_j(t), HL(t) = \frac{1}{q(t)} \sum_{j=1}^{q(t)} hl_j(t), CL(t) = \frac{1}{q(t)} \sum_{j=1}^{q(t)} cl_j(t)$ are the average levels of qualifications, health, and education of human resources at the moment of time *t*;

$\%_{mort}$ is the percentage of natural mortality (of the total population);

$eqv(t), ef(t), eh(t), ec(t), enr(t), es(t)$ refer to the effectiveness of product investment in advanced training, in fixed assets, in healthcare, in education, in environmental protection, in R&D at the moment of time *t*, expressed in the growth of qualification potential, of fixed assets, of the total health and enlightenment potential, of natural resources assessment attributable to the investment of the product unit;

$e\inf(nma(t)), e\inf(nma(t)), einm(nma(t)), einec(nma(t))$ is the dependence of coefficients of reducing the capital-output ratio, labor intensity, material and energy consumption, and non-environmentally friendly production operations at the cost of innovation and modernization operations on the value of intangible assets at the moment of time *t*;

kvf is the coefficient of disposal of fixed assets per unit of time;

$p_{\min}$ is the subsistence level in the consumption of the product by individuals; the model assumes that under-consumption increases mortality and the presence of an excess product increases fertility;

p_{pub} is the amount of product per capita needed to ensure public safety and public administration;

$zm(t)$ is the coefficient of damage to natural resources resulting from mining and energy production at the moment of time *t*.

Some values indicated in (2) as time-dependent can be considered constant in the first approximation.

Given the complex nature of risks in this process, the authors suggest describing the influence of uncertain factors in simulation as random perturbations with given distributions of all model variables, including the shares of the available product, allocated by a single player (the current government) for various purposes (accounting for corruption, natural disasters, negligence).

In the presented model, the operating side at any time divides the product produced according to the directions of its use – for restoring and increasing fixed assets, for consumption and public administration, for nature conservation, for improving qualification of human resources, for healthcare, for education, for R & D, for innovation and modernization operations, seeking to increase its total assets *F(t)*.

Innovations improve labor intensity, capital intensity, material intensity and environmental friendliness of the production operation. The efficiency of innovation depends on the accumulated IA, the effectiveness of R & D, on qualification and enlightenment levels of the population. The effectiveness of all operations depends on the level of public health. The state of natural and human resources affects the amount of optimized functionality of total assets (national wealth) of a country. In the absence of uncertainties, this game problem degenerates into an optimization task, the solution of which shows the growth rate limits of national wealth. If there are uncertainties with the given probability distributions, the same estimates can be made by accessing the mathematical expectation of the required estimates (maximum growth rates of national wealth or the other indicator under the best management, growth rates under different management).

It seems appropriate to use the state (region) security criterion proposed in (Shumov, 2016) as one of the criteria evaluating the attractiveness of a development scenario for the EAEU or for one of its member countries. In this approach, the security function is represented as a product of sovereignty (development) function of a state (region) and its conservation function. The function of sovereignty depends on the share of the given state (region) in the population and the territory, in the planet's GDP as a whole or in the leading state in the group under consideration. The preservation function depends on its ethnic composition and parameters of attracting various ethnic groups. However, the estimates of sovereignty and preservation functions may vary from (Shumov, 2016).

3. Results

Using the models under consideration, it is possible to implement a software complex of simulating various scenarios for the distribution of Gross Domestic Production (GDP) or Gross National Production (GNP) by the basic directions of its use in each EAEU member country, in the EAEU in general, and in hypothetical extensions or restrictions of the EAEU. At the same time, when simulating each such scenario, the expected dynamics of the number and quality (average levels of qualifications, health, enlightenment) of population, the integrated assessment of natural resources, GDP, cost of fixed assets, integrated labor intensity, capital intensity, energy consumption and environmental sustainability will be assessed at the considered time interval. Imitation of each scenario will allow modeling different subscenarios with different patterns of implementation of uncertain factors.

The use of optimization calculations within the framework of the proposed software package will allow determining optimal strategies for managing the distribution of GDP or GNP (management exercised largely by the state) in order to maximize a macroeconomic indicator (GDP, number and qualification potential of population, assessment of natural resources, net or total assets, public security, etc.).

The initial data required for simulation include the initial values of all variables listed in the description of the proposed single-product autarkic operating game model.

In the process of development and improvement of the proposed software package, the authors suggest using more complex operating game models (multiproduct, non-autarkic, with several interacting macro-agents). This will result in expanded, detailed macroeconomic estimates.

4. Discussion

The expected objections of potential opponents to the proposed approach might include the following:

1) The proposed approach lacks innovation, the described basic macroeconomic model is uncompetitive compared with similar models (modifications of Forrester's world dynamics model, and other macroeconomic models).

2) Correct estimates of initial data required for the implementation of the proposed simulation model in relation to the EAEU and its member countries cannot be obtained.

To respond to the first type of objections, it is worth noticing that there are very few complete economic and mathematical models of social processes. Furthermore, there are even fewer conceptual ideas about the life of societies which can serve as a basis for creating such models. The highly simplified concept of Marx, which divides society into two classes (exploiters and exploited) and is based on the "labor theory of value", which does not suggest any relevant approach to measuring labor, still remains topical, shared by many experts in economic and mathematical modeling. The significantly advanced concept by Keynes can be considered dominant in modern macroeconomics. The approach presented in this paper might be considered neo-Keynesian, which suggests considering society as a macroorganism with interrelated systems and functions. At the same time, Keynesian and neo-Keynesian analysis of solvent (effective) and insolvent demand, combined with production capabilities and public administration, is complemented by a more detailed macroeconomic review of educational, health, and environmental processes that are critical for the life of society. This is a fundamental conceptual advancement and it is needless to discuss the lack of innovation in the proposed approach.

In the development of econometrics, one should not be afraid of impossibility to obtain the correct source data required for the implementation of the proposed simulation system.

The paper describes the brainware needed to develop a software package that, in the first approximation, allows for simulation and evaluation of the socio-economic development scenarios of the EAEU in general and each of the EAEU member countries. When using the described single-product autarkic model, the scenario forecasts will be presented in the form of the expected GDP dynamics, the integral production capacities of fixed assets, the number and the average level of health, the qualifications and enlightenment of population, and the integral state of natural resources. The most interesting possibility of such simulation is the possibility of a fairly correct assessment of the growth potentials for a given period of each of the listed macroeconomic indicators under various assumptions about the implementation of uncertain factors (the proposed game model implies a single player and a degenerate "game with nature", which allows for addressing optimization of socio-economic policy in order to maximize the final GDP, human resources, total assets, including net assets in the conventional sense and correct valuation of human and natural resources).

When using more complex and extensive game models of the same class, it is possible to develop a software package with much greater capabilities.

5. Conclusion

The paper develops criteria and approaches to simulating the development of the EAEU and its member states. The authors formulate the requirements for initial data required for such simulation.

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