DIFFERENT APPROACHES OF SIMULATION MODELING IN FORECASTING SOCIO-ECONOMIC SYSTEMS

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Abstract

The article considers various approaches of simulation modeling, highlighting the weak and strong points of each of them, analyses the existing approaches and the constructed models, compares the results and draws conclusions about the applicability of simulation models. Also the article considers the possibility of combining different approaches of simulation modelling to achieve better forecasting results. On the basis of this study there are assumptions about the future usage of simulation modelling for forecasting of socio-economic development.

Simulation modelling can be used to avoid the counterintuitive behaviour of the socio-economic system. It should be borne in mind that in the simulation model must be prescribed the correct cause-effect relationships. With the help of modelling, it was possible to understand the internal mechanisms of the development of various economic processes, hiding behind a visible, often seemingly paradoxical, picture of economic phenomena that did not fit into well-known theoretical schemes. Experience in the use of models has shown that they serve as a reliable tool for analysing macroeconomic patterns, as well as predicting the consequences of macroeconomic decisions, provided that the existing relations are maintained.

During crisis and unstable economic development management decisions are characterized by high dynamism, complexity, multi-dimensionality and the presence of overlapping flows of control actions. Clarity, efficiency, completeness, consistency and scientific validity of decisions taken at the regional level is the key to development of the territory. In this regard, the study of socio-economic development of the region becomes especially important.

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1. INTRODUCTION

The aim of any mathematical model is to simplify the existing reality, to depict it in such a way as to help the researcher better understand the reality being studied, to reveal the basic laws and relationships. Simulation modeling is an experimental way of studying reality using a computer model. The use of computer technology and the possibility of repeated experiments on the simulated system led to the appearance and wide distribution of simulation models.

In this article we will try to understand the essence of the imitation method and the features of the simulation models.

2. BASIC PRINCIPLES OF THE SIMULATION MODEL CONSTRUCTION

Let's consider the basic elements of the simulation model. Usually four main elements of the system are identified (Figure 1):

• the real system under study;

• Logico-mathematical model of the modeled object with the identification of cause-effect relationships;

• simulation (machine) model;

• The computer and the software environment in which imitation is performed.

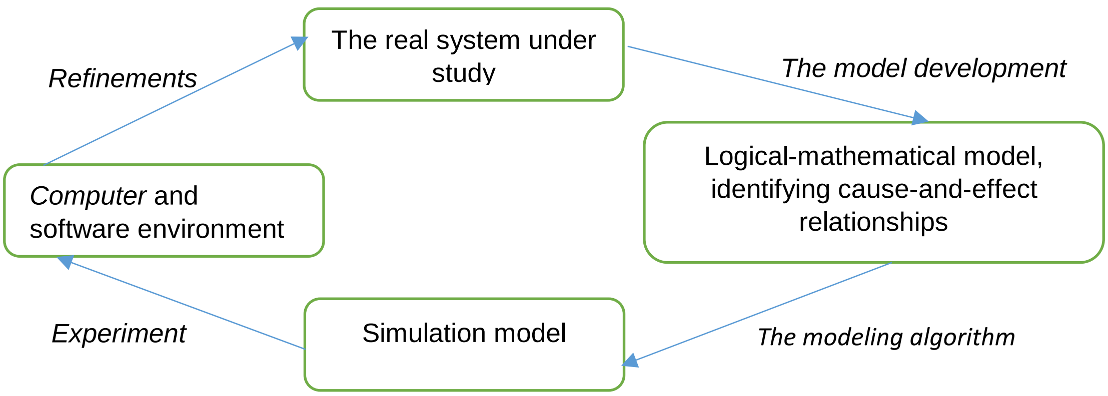

Fig. 1. Elements of the simulation model and the modeling process

The first, the most difficult and important stage in the construction of the simulation model is the planning stage, the definition of the simulation objectives, the boundaries and the framework of the simulated event. The more accurately and deeper the mechanism of cause-effect relations will be worked out, the structural elements will be formalized, the more accurately the model will be. For the adequacy of the model, any nuances that at first glance may seem insignificant are important. It should be noted that the construction of simulation models occurs consistently from simple to complex, by refining the model already built. However, the basic elements and links should be correctly identified in the first stage.

Further, a logical-mathematical model / model of agents' behaviour (in case of agent modeling) and cause-effect relations describing the system under study is developed. It can be presented as computer tables, flowcharts, diagrams, drawings, graphs, displaying the structure and interrelationships of model elements.

It should be noted that the level of mathematical study should strive for optimal. It is incorrect to believe that the more complex the mathematical tools are used, the more reliable the model and its results will be. Sometimes high-level mathematical formulas only complicate the system, missing the essence of the phenomenon, and also making it difficult to analyze the results. So, to develop a marketing strategy, there is no need for a complex mathematical study, it is more important to reproduce the logic of consumer behaviour.

For the software implementation of the described model, it is necessary to translate the logical-mathematical model into a computer program, an algorithm describing the structure and logic of interaction of elements including random factors. This will be an imitation model that can be used to carry out a computational experiment or a series of experiments that are critically analyzed. As a result, the model is revised, updated, and the necessary improvements are made. Having received and analyzed the results of modeling, they must be interpreted with respect to the object of modeling. In other words, this is a transition from the information obtained as a result of the computer experiment with the model to information about the modeling object, on the basis of which conclusions will be made regarding the characteristics of the process of functioning of the system under study.

The experiment is repeated until the model does not adequately correspond to the actual situation, or it will reach a confidence threshold.

The question of the reliability of the results is also very important. What results can be called acceptable? It should be noted that the result of simulation modeling is not the forecast as such, a numerical value, but a range of values that allows to identify trends and relationships within the model, thereby revealing some dynamics. This imitation models differ from classical models, which fix static basic regularities in any time interval.

Static and dynamic approaches to simulation modeling are singled out. Static models are systems of equations that are solved once. The result will be a static description of the system, the selection of the structure, the interrelationships of the composite elements. A quantitative assessment of the model parameters is possible.

3. DIFFERENT APPROACHES OF SIMULATION MODELING

3.1. System-dynamic models

Dynamic models include another variable - time. Mathematical calculations of process parameters are performed at different time intervals, thus allowing the model developer to investigate the development of the system in time. In turn, dynamic models are of two types: continuous and discrete. In continuous models, time varies linearly, and the process - in direct dependence on time. In discrete models, variables are events and time intervals. Thus, a complex system is represented as a model with three components: $\langle A, S, T \rangle$, where A is the set of model elements, including the external environment; S-set of admissible relations, logical connections between elements; T-set of instants of time.

For a dynamic description of the system, it is necessary to introduce concepts of the states of the elements of the system, to describe possible values and to set the rules for their transition from one state to another. At the same time, a random component can be included, the irrationality of the decision-making of individual individuals is taken into account. Having certain operational transition rules, it is possible to describe the functioning of the simulation model in time, preserving the logic of interaction of individual elements.

System-dynamic models describe the behaviour of the system and its structure in the form of a series of interacting both positive and negative feedbacks, as well as time delays. The system approach builds graphical diagrams of cause-effect relationships and influences of global factors on various parameters, and then creates a computer model on the basis of these diagrams. When modeling in this way, they operate not with separate economic objects, but with aggregated elements (aggregated buyer, aggregated service provider). In this way, the individual subjects are depersonalized, their behaviour is seen as economically efficient and rational. This assumption can lead to inadequate results of the forecast, since the rationality of decision-making by individuals is a highly controversial issue. Conditions can go beyond the scope of research; it cannot be possible to predict them.

With the help of system dynamics, it is possible to forecast the dynamics of changes in the basic socio-economic parameters of the region due to the presence of differential equations, as well as dependencies on lag variables obtained by the tools of econometrics or neuroinformatics. System dynamics can identify cause-effect relationships and global interdependencies in the system under consideration.

3.2. Discrete-event models

Discrete-event models work with passive transactions or service requests. Each event occurs at a certain point in time and is marked as a change in the state of the system. Between successive events it is assumed that no changes are taking place in the system. Thus, the model can go directly from one event to another. As a transaction can act as an employee, and raw materials, a signal, a resource and another object of economic activity. Moving around the model, transacts become queued for single-channel and multi-channel devices, occupy, and then release them, and then they are destroyed. The rules governing the order in which these actions occur and the conditions for them can be extremely complex. Each transaction can be assigned characteristics that determine its behaviour in the system. The duration of the activities is usually given by the probability distribution function.

3.3. Agent-based models

Agent-based modeling is a fairly new direction, taking into account both the individual behaviour of active objects (agents) and their interactions. Models based on the agent approach consist of dynamically interacting agents according to certain rules. With the help of this approach, it is possible to create such systems that complexity is comparable to the real world. Unlike system dynamics, the agent approach can allow to operate not by generalized elements of the system, but by the whole set of agents with a certain characteristic set (for example, agents-consumers, agent-producers) can act as such agents. The aim of agent models is to get an idea of these global rules, the general mode of action of the system, based on assumptions about the individual and private behaviour of its individual active parts and the interaction of these parts in the system. In a sense, agent models can be a complement to traditional analytical methods. Where analytical methods allow only to characterize the equilibrium of the system, the agent approach allows the possibility of creating this equilibrium. This feature can become the main advantage of agent modelling. Agent models can also be used to determine critical points, defined as points in time, in which interventions can be critical and change the way forward of the system. In the case of creating a simulation model of economic systems that have significant numbers of active objects (people, machines, enterprises, projects, assets, goods, etc.), which are united by the presence of elements of individual behaviour, agent modelling becomes the most universal and powerful approach, since it has the ability to take into account the complexity of the structure and any of its behaviour.

The most suitable for creating models of socio-economic systems are agent and system-dynamic methods. This is due to the different approaches of economic theory. The most widespread and developed in our time is the neoclassical economic school, which describes the economy as limiting values. These models are represented in the form of systems of differential equations and, consequently, correspond to the methodology of system dynamics. The model, created on the basis of combining different approaches, uses system dynamics at a high level of abstraction (for describing the behaviour of macro systems), whereas agent modelling is at low (to describe the behaviour of individual economic agents), so that a more accurate reflection of socioeconomic dynamics can be achieved.

Agents can include system-dynamic diagrams, rules of behaviour algorithms, variables, and state diagrams. The model created with the help of the presented research methodology has the ability to predict the development of the socio-economic system, subject to the impact of various factors, and to determine the most optimal management strategy. During the research, it is possible to carry out experiments to determine the optimal values of individual indicators optimizing the objective function.

The combination of these two approaches will significantly improve understanding of socio-economic processes, and managers make more informed decisions based on more reliable data.

4. CONCLUSION

In conclusion, it should be said that the development of agent and system-dynamic modelling, as well as software in the field of simulation, can open up to the scientists great prospects for further research of problems that may arise in modelling effects from possible impacts of various external and internal factors affecting stability of a particular system.

The key advantages of simulation are the following:

• the possibility of describing complex systems characterized by a multitude of nonlinear relationships and a large number of heterogeneous variables;

• reproduction of behavioral aspects and dynamic environmental processes;

• the ability to identify patterns, dynamics and trends in the development and operation of a complex economic system in the absence of accurate information or its small number;

• description of the behaviour and interaction of the set of active agents in the social systems under study;

• implementation of the possibilities of object-oriented design and application of high-tech solutions in computer simulation, etc .;

• use of a modular structure when creating an information system based on them, since this approach has the ability to use the resources of the available equipment with the greatest efficiency, which in turn reduces the processing time of data;

• the possibility of monitoring the indicators at all stages of modelling, both in a complex and separately.

Naturally, simulation models are not without flaws. First of all, it is worth noting the high cost of the very development of the simulation model. Thus, for a regional model, the involvement of more than one specialist is required, even more- the whole team. Time costs for building a similar model are also great.

Simulation modelling can be used to avoid the counterintuitive behaviour of the socio-economic system. It should be borne in mind that in the simulation model must be prescribed the correct cause-effect relationships. If you set only visible or seemingly logical causal connections, you can get a picture that has no connection with reality. In this case, the model will live its own life.

From the point of view of implementing the results of modeling, it is worth noting the need for financial and information support, as well as training of personnel of state authorities in the region. Also, there is a difficulty in collecting the source data for the simulation model. They are not always collected and analysed by Rosstat. This can significantly reduce the adequacy of the model.

Thus, it can be noted that the model, created on the basis of combining different approaches, will use the system dynamics at a high level of abstraction (for describing the behaviour of macro systems), and agent modeling at a low (for describing the behaviour of individual economic agents), so that there is the possibility of a more accurate description of social and economic dynamics of the region.

With the help of modeling, it is possible to understand the internal mechanisms of the development of various economic processes, hiding behind a visible, often seemingly paradoxical, picture of economic phenomena that did not fit into well-known theoretical schemes. Experience in the use of models has shown that they serve as a reliable tool for analysing macroeconomic patterns, as well as predicting the consequences of macroeconomic decisions, provided that the existing relations are maintained.

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