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MATHEMATICAL METHODS OF ECONOMIC ANALYSIS SOLVING PROBLEMS

МАТЕМАТИЧНІ МЕТОДИ РОЗВ'ЯЗАННЯ ЗАДАЧ ЕКОНОМІЧНОГО АНАЛІЗУ

The use of mathematical methods in economic analysis is the most important direction for improving management systems. Mathematical methods speed up economic analysis, increase the accuracy of calculations and more fully take into account the impact of factors on productivity. The use of mathematical methods requires: – development of mathematical models reflecting quantitative indicators of system activity of the organization's employees, processes occurring in complex enterprise-type systems; – a systematic approach to the study of this object, taking into account its relationships and connections with other objects (enterprise, firm); – improvement of the enterprise management information system with the help of IT technologies. Solving tasks of economic analysis by mathematical methods is possible only when constructing mathematical, that is, real economic relations and dependencies of expressions using mathematical analysis. This calls for the development of mathematical models. Mathematical methods play an important role in economic analysis, as they can provide accurate calculations and full accounting of the influence of factors using short-term forecasting methods and management decision-making at the enterprise. The article highlights the results of research and development in the field of analysis of economic processes and systems based on the use of economic and mathematical methods and tools. The mathematical apparatus of economic research was developed and it was proposed to integrate applied methods and solutions into efficiency improvement tools. The model approach, which arose in the ancient sciences, gradually turned into a universal method of scientific knowledge. Currently, the use of mathematical methods in the analysis of economic processes is indispensable both from the point of view of a more serious substantiation of theoretical concepts and the ability to quantitatively determine economic relations. The research presented in the article will be useful for everyone who is interested in the theory of mathematical methods of economics. Some of the presented methods and models can be used directly by practitioners in this field.

Key words: *economics, mathematical methods, economic research, mathematical analysis, economic-mathematical modeling.*

Використання математичних методів в економічному аналізі – найважливіший напрямок удосконалення систем управління. Математичні методи прискорюють економічний аналіз, підвищують точність розрахунків і повніше враховують вплив чинників на продуктивність. Використання математичних методів вимагає: – розробки математичних моделей, що відображають кількісні показники системної діяльності співробітників організації, процесів, що протікають у складних системах типу підприємств; – системного підходу до вивчення даного об'єкта з урахуванням його взаємовідносин та зв'язків з іншими об'єктами (підприємством, фірмою); – удосконалення інформаційної системи управління підприємством за допомогою IT-технологій. Вирішення завдань економічного аналізу математичними методами можливе лише при побудові математичних, тобто реальних економічних відносин та залежностей виразів з використанням математичного аналізу. Це викликає необхідність розробки математичних моделей. Математичні методи відіграють важливу роль в економічному аналізі, оскільки вони можуть забезпе-

чити точні розрахунки та повний облік впливу факторів за допомогою короткострокових методів прогнозування та прийняття управлінських рішень на підприємстві. В статті висвітлено результати досліджень та розробок у галузі аналізу економічних процесів та систем на основі використання економіко-математичних методів та інструментів. Розроблено математичний апарат економічних досліджень та запропоновано інтегрувати прикладні методи та рішення до інструментів підвищення ефективності. Модельний підхід, що виник в античних науках, поступово перетворився на універсальний метод наукового пізнання. В даний час використання математичних методів при аналізі економічних процесів незамінне як з точки зору серйознішого обґрунтування теоретичних концепцій, так і здатності кількісно визначати економічні відносини. Представлені в статті дослідження будуть корисні для всіх, хто цікавиться теорією математичних методів економіки. Деякі з представлених методів та моделей можуть бути використані безпосередньо практикуючими фахівцями у цій галузі.

Ключові слова: *економіка, математичні методи, економічні дослідження, математичний аналіз, економіко-математичне моделювання.*

Formulation of the problem. The use of mathematical methods in economics is the most important direction for improving management systems. Mathematical methods speed up economic analysis, help to more fully take into account the impact of factors on productivity and increase the accuracy of calculations. The use of mathematical methods requires:

– a systematic approach to the study of a specific object, taking into account its relationships and connections with other objects (enterprises, firms);

– development of mathematical models reflecting quantitative indicators of system activity of the organization's employees, processes occurring in complex enterprise-type systems;

– improvement of the enterprise management information system with the help of IT technologies.

Analysis of recent research and publications. Although the use of mathematical methods in the study of economic problems is actually a widely analyzed topic, this study provides a new, modified analysis of these methods. "Inflation Targeting in Emerging Economies: What Does the Evidence Say?" [4]; "Does Inflation Targeting Matter in Developing Countries?" [5]; "On the nonlinear relationship between inflation and economic growth" [3]; "Management decision-making models", "Possibilities of applying linear optimization with imprecise data in game-theoretic models of resource allocation".

Constant quantitative and qualitative changes both in production and in the environment require the development of specific methods that facilitate the justification and selection of management decisions regarding complex technical, organizational and economic problems in conditions of uncertainty of information used in management decisions. The purpose of writing this article is to ensure the development of these methods.

Formulation of the purpose of the article. Mathematical solutions to the problems of economic analysis are possible when they are formulated mathematically, that is, real economic relationships and dependencies are expressed using mathematical analysis. The purpose of operational research is to combine interdependent elements of the system, which provides the best economic indicators.

Presentation of the main research material. Different methods are used to solve economic problems in management practice. The classification symbols chosen are arbitrary. For example, different mathematical methods are used in network planning and management, and many authors interpret different meanings of the term "operational research".

Elementary mathematical methods are used in traditional economic calculations when justifying the need for resources, preparing plans, projects, etc.

Classical methods of mathematical analysis are used independently (differentiation and integration) and as part of other methods (mathematical statistics, mathematical programming).

Statistical methods are the primary tool for studying mass, recurring events. They are used when it is possible to present changes in the analyzed indicators as a random process.

If the relationship between the analyzed features is not deterministic, but stochastic, statistical and probabilistic methods become practically the only research tool. Many methods of paired correlation analysis are known in economic analysis [5].

At the same time, the study of statistical aggregates uses the law of distribution, a number of variations, and the sampling method. Correlation, regression, variance, covariance, spectral, component, and factor analysis are used for highly variable statistical groups. Economic methods are based on the synthesis of three fields of knowledge: economics, mathematics and statistics.

The basis of econometrics is an economic model, that is, a schematic description of an economic phenomenon or process, a display of their characteristics using scientific abstraction. The most common method of economic analysis is "input-output". The method is based on a checkerboard pattern and is a matrix (balance sheet) model that clearly demonstrates the relationship between costs and production results.

Mathematical programming methods are the main tool for solving problems of optimization of production and economic activity. In fact, the methods are a means of planned calculations, and they allow you to assess the intensity of planned work, the meagerness of the results, and identify a limited number of groups of raw materials and equipment.

Operations research means the development of methods of purposeful actions (operations), quantitative assessment of solutions and selection of the best of them.

Game theory as a part of operations research is a theory of mathematical models of optimal decision-making under conditions of uncertainty or conflict between several parties with different interests.

Sequence theory, based on probability theory, explores mathematical methods for quantifying alternating processes. One of the features of all civil service duties is that the events under investigation are random in nature. The time intervals between the number of service requests and their arrival are random, but in general, quantitative research obeys the statistical laws that are the subject of queuing theory.

Economic cybernetics analyzes economic events and processes as complex systems from the point of view of management laws and the flow of information in them. The methods of modeling and system analysis are the most advanced in this field.

The use of mathematical methods in economic analysis is based on the methodology of economic-mathematical modeling of economic processes and scientifically based classification of analysis methods and tasks. All economic-mathematical methods (tasks) are divided into two groups: optimization solutions according to a certain criterion and non-optimization solutions (solutions without optimality criteria). According to the principle of obtaining an exact solution, all mathematical methods are divided into two parts: exact (based on criteria or a single solution already obtained) and approximate (based on stochastic data) [4].

Methods of optimal accuracy include methods of the theory of optimal processes, some methods of mathematical programming and methods of operations research, optimization of approximations includes mathematical programming, operations research, economic cybernetics, and some heuristic methods. Non-optimized exact methods include methods of elementary mathematics and classical mathematical analysis, economic methods, non-optimized approximate methods include methods of statistical tests and other mathematical and statistical methods. Mathematical models of queues and inventory management are especially often used.

The theory of queues. This theory makes it possible to study systems designed for a mass flow of random requests. Both the moments of the requirements and the time spent on servicing them can be random. The purpose of theoretical methods is to find a reasonable service organization that ensures the given quality, to determine the optimal (from the point of view of the accepted criteria) service standards, the need for which arises unplanned, irregularly. Problems of a mathematically formulated theory are usually reduced to the study of a certain type of random processes.

Mathematical models of many technical and economic problems are also problems of linear programming. Linear programming is a discipline devoted to the theory and methods of solving multiplicity of linear functions defined by systems of linear equations and inequalities.

The problem of enterprise planning. Various factors of production for homogeneous products: raw materials, labor, machinery, fuel, transport, etc. are required for management. Usually, there are several proven technological methods of production, and in these methods, the costs of production factors per unit of product production time are different. The amount of production factors consumed and the amount of products produced depend on how long the enterprise will work with one or another technological method. The problem lies in the rational distribution of the company's working time from various technological techniques. The maximum number of products will be produced with a certain limited cost of each factor of production [1].

Operational research also touches on many important issues that require a special solution based on the method of mathematical modeling, among them:

1. The problem of product reliability.
2. The task of replacing the equipment.
3. Theory of planning (theory of schedules).
4. The problem of resource allocation.
5. The problem of assessment.
6. Theory of network planning.

Product reliability problem

The reliability of products is determined by a number of indicators. There are recommendations for choosing reliability indicators for each type of product. To evaluate products that can be in two possible situations, the following indicators are used for operation and failure: average failure time (average time to the first failure), failure intensity, failure flow parameter, average recovery time, t probability of a failed operation, availability ratio.

The problem of resource allocation. The issue of resource allocation is one of the key issues in the production management process. To solve this problem, the field of operational research uses a statistical model.

Price is a problem. The issue of product pricing plays an important role for the enterprise. Its profit depends on how prices are conducted at the enterprise. In addition, in today's market economy, price has become an important factor in competition.

Theory of network planning. The network is a management planning system for planning and management, development of large economic complexes, design and technological preparation for the production of new types of goods, construction and reconstruction, major repairs of fixed assets using network schedules [3].

The essence of network planning and management is to make a mathematical model of the controlled object, such as a network diagram or a model in the computer's memory, which reflects the connection and duration of a certain set of works. A network graph is used for operational control after optimization using applied mathematics and computer technology.

Solving economic problems using the method of mathematical modeling allows effective management of individual production processes at the level of forecasting and planning of economic situations, as well as making management decisions based on all this. As a result, mathematical modeling as a method is closely related to the theory of decision-making in management.

Stages of economic and mathematical modeling. The main stages of the modeling process acquire their characteristics in various fields of knowledge, in particular in economics. We will analyze the sequence and content of the stages of the economic-mathematical modeling cycle.

1. Formation of an economic problem and its qualitative analysis. The main thing here is to clearly formulate the essence of the problem, the assumptions made and the questions

that need to be answered. This stage includes the selection of the most important features and characteristics of the modeled object and abstraction from secondary ones; study of the main dependencies that combine the structure and elements of the object; formation of hypotheses explaining the behavior and development of the object.

2. Building a mathematical model. This is the stage of formalization of the economic problem, its expression in the form of special mathematical dependencies and ratios (functions, equations, inequalities, etc.). Usually, the basic structure (type) of the mathematical model is determined first, and then the details of this structure (special list of variables and parameters, transition form) are determined. Thus, the construction of the model is divided into several stages.

It is a mistake to think about how many facts the model takes into account, how well it works. Forms of mathematical dependence used in the model (linear and non-linear), accounting for coincidence and uncertainty factors, etc. should be taken into account. The extreme complexity of the model complicates the research process. It is necessary not only to take into account the real possibilities of data and mathematical support, but also to compare the cost of modeling with the obtained effect (increase in cost, effect with increase in model complexity).

One of the important features of mathematical models is the possibility of their use for solving problems of different quality. So, even when faced with a new economic problem, there is no need to make efforts to "invent" a model; First, you need to try to apply already known models to solve this problem.

When building the model, two systems of scientific knowledge are compared: economic and mathematical. It is natural to try to obtain a model for a well-studied class of mathematical problems. Often this can be done by slightly simplifying the initial assumptions of the model without distorting the main characteristics of the modeled object. However, such a situation is possible even if the formalization of the economic problem leads to a previously unknown mathematical structure.

3. Mathematical analysis of the model. The purpose of this step is to clarify the general characteristics of the model. Purely mathematical research methods are used here. The most important point is the proof of the existence of the solution in the formed model (existence theorem). If it is possible to prove the absence of a solution to a mathematical problem, then there is no need to work on the original version of the model any more; It is necessary to adjust either the formation of the economic problem or the methods of its mathematical formalization. Analytical research of the model, for example, specifies a single solution, which variables (unknown) can be included in the solution, what are the relationships between them, within what limits and depending on the initial conditions of change, what are the trends of change, etc. the advantage is that the obtained results compared to empirical (numerical) results are reliable for different specific values of external and internal parameters of the model. Knowing the general characteristics of a model is so important that researchers often deliberately idealize the original model in order to prove such features. Again, it is very difficult to analyze models of complex economic objects. If analytical methods do not allow studying the general characteristics of the model and the simplification of the model leads to unacceptable results, they resort to numerical research methods.

4. Preparation of reference information. Modeling makes serious demands on the information system. At the same time, the real possibilities of obtaining information limit the choice of models of practical use. This takes into account both the fundamental capabilities of data preparation (for a certain period), as well as the cost of preparing relevant data arrays. These costs should not exceed the impact of using additional data.

In the process of data preparation, probability theory, theoretical and mathematical statistical methods are widely used. The output data used in some models of systemic economic-mathematical modeling are the result of other models.

5. Digital solution. This stage includes the development of algorithms for the numerical solution of the problem, the development of computer programs and direct calculations. The problems at this stage are primarily related to the large size of economic problems and the need to process a significant amount of information.

In general, nowadays calculations based on economic and mathematical models are very variable. Thanks to the high speed of modern computers, it is possible to conduct numerous "model" experiments, studying the "behavior" of the model under various changes in certain conditions. Digital research can significantly complement the results of analytical research and is the only option for many models. The class of economic problems that can be solved by digital methods is wider than the problems existing for analytical research [2].

6. Analysis of numerical results and its application. At this last stage of the period, the question arises about the accuracy and completeness of the modeling results and the degree of their practical application.

Mathematical verification methods can reveal erroneous model structures and thus narrow down the class of potentially correct models. Informal analysis of theoretical results and numerical results obtained using the model, comparison with existing knowledge and facts of reality, economic problem, constructed mathematical model, its data and mathematical support.

Conclusions. Alternative goals (targeting monetary aggregates or stabilizing the exchange rate) provide a significant increase in the external and internal parameters of the model compared to discretionary monetary policy only for certain groups of countries: for economies with a transition economy and a high level of diversity. At the same time, the quantitative assessment of the scale of this impact is still low against the inflation target. The fact that these monetary policy regimes are still used by a number of countries can be explained only by the relative technical simplicity of their implementation, as well as the insufficient development of financial markets for the transition to inflation targeting. This debate is supported only by their popularity among developing countries. As financial markets develop and monetary policy instruments improve, it is recommended that such an economy creates the preconditions for a transition to pure or mixed inflation targeting [3].

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