DISCUSSION

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Mathematics and economics in the Möbius space: a systems view on the interdisciplinary technologies of cognition

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Abstract. Relations between mathematics and economics as closely interrelated fields of knowledge have been examined in the paper. Despite the centuries of extended debates over this issue the necessity to reconsider requirements for collaboration between mathematics and economics has appeared in today's rapidly accelerating scientific and technological progress, turbulent economic environment, development of new means of communication, analytics, and decision-making. The general and distinctive features of these disciplines have been explored, and the structural and functional prerequisites and goals for their coordinated and synchronized development have been identified. The results are applied to the processes of economic-mathematical and computer modeling, including construction, analysis and interpretation of models. The principles of evidence-based modeling, which are of a special attention to all stages of modeling, have been emphasized. The feasibility of using the Möbius strip as a space for the coevolutionary development of mathematics and economics is demonstrated. The goals and the objectives of this study are to define principles and methods for organizing effective and reliable interaction between mathematics and economics, both at the macro-scale of disciplinary and interdisciplinary development and at the micro-scale of developing specific economic-mathematical models. Systems analysis of the fundamental, natural and social sciences and humanities is used as a methodological basis. The requirements for the mathematization of economics and the economization of mathematics as perspective areas of interaction between the disciplines have been substantiated and structured.

Keywords: economics, mathematics, modeling, Möbius space, interaction of mathematics and economics

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АКТУАЛЬНАЯ ТЕМА/ДИСКУССИЯ

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Математика и экономика в пространстве Мебиуса: системный взгляд на междисциплинарные технологии познания

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Аннотация. В статье рассматривается соотношение между математикой и экономикой как тесно взаимодействующими друг с другом областями знания. Несмотря на многовековое обсуждение этого вопроса, в современных условиях резкого ускорения научно-технического прогресса, турбулентности экономической среды, создания новых средств коммуникации, аналитики и принятия решений возникает необходимость пересмотра требований к коллаборации математики и экономики. Исследуются общие и отличительные особенности этих наук, определяются структурные и функциональные предпосылки и цели их согласованного и синхронизированного развития. Результаты проецируются на процессы экономико-математического и компьютерного моделирования, включая построение, анализ и интерпретацию моделей. Акцентируются принципы доказательного моделирования, требующие особого внимания ко всем этапам моделирования. Показана целесообразность применения ленты Мебиуса как пространства коэволюционного развития математики и экономики при построении и интерпретации результатов моделирования. Цели и задачи исследования связаны с определением принципов и методов организации эффективного и надежного взаимодействия математики и экономики как в макромасштабах дисциплинарного и междисциплинарного развития, так и в микромасштабах разработки конкретных экономико-математических моделей. В качестве методологической основы применяется системный анализ сферы фундаментальных, естественных и социогуманитарных наук. Обоснованы и структурированы требования к математизации экономики и экономизации математики как перспективных направлений взаимодействия дисциплин.

Ключевые слова: экономика, математика, моделирование, пространство Мебиуса, взаимодействие математики и экономики

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INTRODUCTION

The relationship between economics, defined as the science of production, distribution, exchange, and consumption of values, and mathematics, regarded as the science of quantitative relationships (numbers) and spatial forms (geometric figures), has been explored for centuries (Makarov et al., 2022; Blaug, 2004; Karev, 2011; Yushkevich, 1970; Michel & Chemla, 2020; Weintraub, 2002). In this context, the emergence of mathematics as an independent discipline is often linked to the necessity of addressing issues such as measuring and comparing material and financial resources, calculating interest on loans, ensuring fair wages, and similar concerns. Here, mathematics serves as a supportive field in relation to economics. Conversely, the advancement of economics has contributed to the expansion of the subject-functional domain of mathematics, facilitating its development as a professional field for mathematicians. In the following years, the data from these industries evolved along diverging paths, until the late 19th and early 20th centuries when an independent intermediate field emerged – the area of economic and mathematical modeling. By the beginning of the 21st century, this field had expanded its toolkit to include simulation, computer, and cognitive-intellectual modeling (big data, the internet, artificial intelligence).

In the new context, the relationship between mathematics and economics necessitates a re-evaluation at both the macro level of the interrelations among scientific and practical disciplines, as well as at the micro level concerning the relationship between the "mathematical model and the economic object of modeling."

This article examines the relationship between mathematics and economics from the perspective of identifying reserves for enhancing the effectiveness of their collaboration. The issue often transcends the specified disciplines and addresses broader problems of cognition and the transformation of reality. As a methodological tool for this investigation, the image of a Möbius strip is employed – a well-known geometric model of space that embodies the concept of unity and the infinity of the world. Its application allows for the identification of the primary directions for the coordinated development of mathematics and economics as polar yet interconnected scientific and practical disciplines. To this end, the article addresses the research tasks: the common characteristics of these fields of knowledge; their distinctive features; and the dynamics of development within the intermediate sphere of economic-mathematical modeling. The structure is placed within the "world of Möbius" as a space-time continuum, providing an unlimited range for the formation of a systemic worldview in a non-systemic and unstable world.

Mathematics and Economics: Subject-Functional Differences

Some authors believe that the natural language of general economic theory is the language of mathematics (Samuelson, 2002; Dow, 2006; Barlybaev et al., 2009). However, mathematics transcends its linguistic function and constitutes a self-developing, largely autonomous system. In this regard, mathematics and economic theory represent fundamentally different branches of knowledge. While mathematics is based on terms and concepts developed within the discipline itself (natural numbers, rational and irrational numbers, functions, regular polyhedra, and others), economics extensively employs terms and knowledge from related sciences such as sociology, technology, psychology, and others. In this sense, the gap between pure mathematics and pure economics appears to be insurmountable. Between them lies a vast array of knowledge concerning measurement methods, procedures for constructing and interpreting econometric models, and the development of recommendations for improving economic management. It follows that when discussing the adequacy of a particular mathematical or computational model, the focus is not on the alignment between the mathematical model and economic reality, but rather on the model's correspondence to the intermediate information that, on one hand, describes the properties of the model in certain terms, and on the other hand, describes the state of a specific fragment of the economy in different terms.

There are significant differences between the psychological types of scientists working in the field of mathematics, on one hand, and those in the field of economics, on the other. Mathematicians and economists generally possess not only different but also opposing psychological traits (see, for example, (Vinober, 2024)). Here are a few examples:

- while mathematicians are typically introverted, economists are predominantly extroverted;
- mathematicians perceive the world as a collection of separable systems with clear boundaries, whereas economists deal with intermingling systems that have ambiguous boundaries;
- mathematicians are reactive, while economists are proactive;
- mathematicians tend to prefer individual work, while economists are inclined towards collaborative efforts.

The work of a mathematician is often characterized by prolonged periods of unsuccessful attempts to solve a given problem, followed by a brief moment of achieving the desired solution. In contrast, the work of an economist is associated with less dramatic fluctuations between the search process and the actual attainment of a solution. Consequently, the professional endeavors of a mathematician demand more significant willpower than those of an economist.

To gain a deeper understanding of the distinctions between mathematics and economics, let us refer to the classification of sciences based on the characteristics of their subjects of study. Utilizing the methodology of systemic economic theory, we can broadly categorize sciences into four groups:

– Object sciences, which study localized fragments of the subject area that are fixed in space and continue indefinitely over time;
– Process sciences, which examine localized parts of the subject area that are time-bound and mobile in space;
– Project sciences, which investigate localized segments of the subject area that are both time-bound and spatially fixed;
– Environmental sciences, which analyze parts of the subject area that are dynamic in both space and time.

Mathematics is classified as an object science, as its primary units of study are static entities such as numbers, sets, shapes, and similar constructs; whereas economics is categorized as a process science, since its units of research typically involve processes like economic growth, inflation, employment dynamics, and others. Conversely, history, which examines localized events in both space and time, is considered a project science; philosophy, which investigates universal laws governing the development of the world and society, is regarded as an environmental science. Based on this classification, one can conclude that economics and mathematics are, in a certain sense, opposites of each other (more detailed information regarding the characteristics of such polar systems as object and process, project and environment can be found in the theory of notebooks and duality theory (see (Kleiner, 2019)).

Statements originating from mathematics and economics are perceived differently by individuals. While mathematical formulations are regarded as unequivocal, economic ones are seen as relative, contingent upon the time and space of their address, as well as the context in which they are articulated. Consequently, assertions in mathematics are typically deemed objective, whereas evaluations in economics are inherently subjective. This latter aspect is illustrated through statements such as "felt as ...". For instance, an air temperature of −5 °C is felt as −9 °C. This discussion pertains to the significance of the human factor in the intermediary space between mathematics and economics. In fact, the stock market plays a similar role, being shaped by numerous subjective assessments and impacting the actual state of economic systems.

Mathematics and Economics: Common Features

Despite the clear distinctions between mathematics and economics, several common characteristics can be identified. Both disciplines utilize a substantial array of shared terminology: growth and decline; ownership/property; equilibrium; influence/dependence; derivative derivatives; penalties (penalty functions/penalty sanctions); grouping and coordination; "golden ratio"; discreteness and continuity; invariance; family; uncertainty; system and others. Mathematics also employs expressions that may seem purely economic, such as marginal influence (partial derivative), elasticity of substitution, "greedy" algorithms, and more.

Many methods and algorithms from computational mathematics can be adequately described in terms of economic relationships among independent agents, taking into account the analogy between partial derivatives and prices. For instance, the Lagrange multiplier method for finding the conditional extremum of a function has a clear economic interpretation. The same can be said for several other methods used to solve optimization problems, including coordinate descent methods, and gradient descent.

In general, mathematics can be viewed as a specific type of economic activity that encompasses production (the generation of new results), distribution (the placement of obtained results within communication channels with consumers/users of those results), exchange (mutual familiarization with the acquired results and consultations with market participants during seminars, symposiums, and conferences), and consumption (the utilization of external information necessary for the continuation of research). Economic patterns, in an adapted form, also extend to the market of mathematical results, which includes products such as new concepts, theorems, and algorithms. Just as in economics, where object, project, process, and environmental systems interact, mathematics reveals sections that exhibit characteristics similar to those typical of the object, project, process, and environmental sectors of the economy.

Discrete mathematics, including algebra, can be viewed as analogous to the object sector; probability theory, which interprets the probabilities of events through σ-algebras, can be seen as analogous to the project sector; functional analysis and the theory of functions can be likened to the process sector; and topology can be compared to the environmental sector. This perspective allows for the application of research findings regarding the interconnections between the economic system sectors to mathematics, with appropriate modifications.

The most significant connection between mathematics and economics is realized through the term "system." In mathematics, we encounter coordinate systems, variables, dependencies, equations, and more. In economics, we find systems of interests, institutions, constraints, and other systems. During modeling, the following act as systems: the subject of modeling; the modeling apparatus; the modeling process (coordination of modeling stages); the objectives of modeling; and the interpretation of modeling results. Understanding the universality of the system concept forms the foundation of what is known as systems thinking and systems modeling (Kleiner, 2013; Morozov, 2016; Gorelov et al., 2012; Cherkashin, 2019). The development of systemic methodology based on the general theory of systems and spatiotemporal analysis should lead to the establishment of systemic mathematics as the science of the structure and interaction of mathematical systems; systemic economics as the science of the creation and interaction of economic systems; system modeling as a system of methods for constructing and investigating the relationships between mathematical and economic systems. Consequently, one of the objectives of both economic and mathematical education is to cultivate researchers and participants in economic activities who possess knowledge and skills across all three domains: systemic mathematics, systemic economics, and system modeling. It can be asserted that there is a need to transition from the concept of homo economicus ("economic man") as the ideal participant in economic activities to the preferred model of homo systematum ("systemic man"). Addressing this challenge will necessitate significant alterations in the structure and objectives of not only higher and secondary education but also primary education in Russia.

Mathematics and Economics: A Path Forward

The enhancement of interaction between mathematics and economics should occur in two directions: the mathematization of economics and the economization of mathematics. The main trajectory of the mathematization of economics is through its axiomatization. The establishment of a series of clearly structured, competing axiomatized economic theories would provide a new perspective on the "expanding universe" of economic theory (Kleiner, 2023a), allowing for a clearer understanding of the interconnections among its segments, the direction, and the asymptotic movement of economic science. Concurrently, it is essential to consider the expansion and deepening of the process of economizing mathematics, bringing it closer to current modeling challenges. This involves not merely broadening the application of the known mathematical apparatus to the construction of economic-mathematical models, but also modernizing several fundamental concepts of mathematics, such as natural numbers, number, set, and membership.

The enhancement of the quality and efficiency of mathematical models in economics is contingent not only upon the selection of variable compositions, the reflection of existing constraints, and the objectives of agents during the search for management solutions, but also on the accurate interpretation of the meanings of the variables included in the model. A detailed analysis reveals that in contemporary real life, the concept of a number as a quantitative result of measurement or assessment is not utilized in the same manner as it is articulated within the framework of mathematics. In the initial stages of the development of mathematics as an independent science, the primary focus of its research was on volumes, quantities, and proportions of material objects. However, over time, the focus of the subject area of mathematics has shifted towards the social and humanitarian sphere. Nevertheless, the fundamental and instrumental categories of mathematics have largely retained their orientation towards modeling the material sphere. The adaptation of mathematics to the contemporary economy necessitates, above all, the incorporation of the human factor across all layers of mathematics – from fundamental categories to the rules of inference and result verification.

The static nature of foundational mathematical objects can be adjusted primarily by considering the position of the researcher within the socio-economic context and time (similar to the consideration of the observer's position in quantum physics). Thus, from a mathematical perspective, all members of the natural number series differ from their neighbors by the same magnitude – one unit. However, this only ensures an accurate interpretation of results when natural numbers are employed to measure the number of participants in a relatively small family. In cases involving families with a large number of participants or indicators with high levels (large numbers), the use of the natural series with equally spaced elements cannot be deemed appropriate.

The foundation of mathematical constructs should be based on a more flexible synthesized natural series, which allows for the joint use of qualitative characteristics such as "large", "medium", and "small" alongside natural measurements. Natural numbers, as elements of the natural series, cannot be adequately utilized by participants in economic activities as natural measures of economic resource volumes when dealing with large quantities of measured units. The hypothetical series should increasingly "blur" and take on characteristics of a continuous structure (continuum) as it moves away from the origin. In relation to measurements in physics, similar considerations were expressed by P.K. Rashevsky (Rashevsky, 1973).

In a similar manner, the concept of a set and, consequently, the notion of membership must be modernized for economic purposes. In most cases, a set in mathematical and economic research is represented as a core (essence) and a periphery (surroundings). Fuzzy or probabilistic criteria for determining whether a given object belongs to a set should reflect the researcher's position regarding the core and periphery of that set: the observer's competence in defining the membership function depends on whether the observer is near or within the core, near or within the periphery, or outside the considered set. The objectives of the research are also of significant importance. For strategic planning or management purposes, a considerably more flexible mathematical framework is required than for short-term regulation. There is a need for the development of a specific branch of mathematics – strategic mathematics, which is based on the concept of a 'soft' natural series and is intended for modeling strategic processes under conditions of uncertainty.

The establishment of effective and proper interaction between mathematics and economics necessitates systematic, mutual, multi-level monitoring of the development of these fields, mutual communication, and, where possible, synchronization of their progress. The forward-looking objective is the co-evolutionary development of mathematics and economics based on the intertwining of these disciplines in the areas of fundamental, theoretical, applied, and problem-oriented research.

The implementation of this research program significantly relies on the methodology and techniques of modeling, specifically the construction and interpretation of mathematical/computer models of economic systems. The works of G.B. Kleiner and A.V. Egorov (Kleiner, 2023b, 2023c; Egorov, 2025) advance the concept of evidence-based modeling, which aims to standardize modeling practices on one hand, and to enhance trust in its outcomes on the other. It is essential to develop a methodology for evidence-based modeling that is grounded in the transparency of the stages and the entire modeling process. This new direction in modeling methodology should ensure the utmost accuracy and reliability of the modeling results. Each phase of evidence-based modeling must be accompanied by an assessment of its effectiveness and safety from the perspective of further progress towards the construction and interpretation of the model. The paradigm of evidence-based modeling could serve as one potential response to the doubts regarding the practical effectiveness of economic science as a whole.

In modeling practice, it is customary to assess the quality of a model based on the degree of alignment between the results obtained through it and the actual data. The concept of evidential modeling, while not dismissing this method of evaluating model quality through its outcomes, shifts the focus to the modeling process itself. This shift is necessitated by the need for industrialization and standardization in model production. Proper execution of evidential modeling procedures (assuming the methodology is sufficiently developed) should generally ensure the attainment of correct results. In other words, from a methodological standpoint, in the context of modeling industrialization, the process of model construction is typically more significant than the final outcome. However, this does not imply that the same holds true for the development of a single specific model. Generally, the question of the relationship between the importance of the process and the result merits separate discussion, the relevance of which has sharply increased recently due to the widespread use of artificial intelligence systems with opaque modeling processes.

A schematic representation of the stages of modeling and their interconnections is illustrated in *Figure 1.* The modeling technology is depicted in the figure as two symmetrically ascending directions: the left side of the figure reflects the flow of empirical information

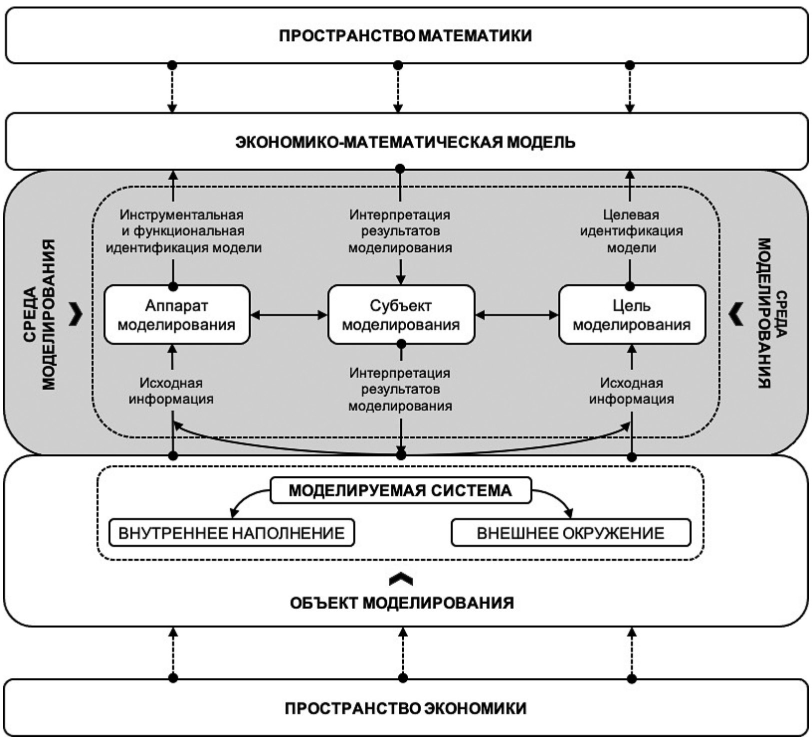

Figure 1. Stylized modeling diagram
Рисунок 1. Стилизованная схема моделирования

Source: *compiled by the author*
Источник: *составлено автором*

regarding the modeling object, while the right side illustrates the flow of information concerning the objectives and conditions of the modeling process. The central part of the figure represents the movement of subjective information, which is utilized both for constructing the model and for its interpretation. The principle of the evidential nature of modeling necessitates heightened attention to all components of the modeling process and the relationships among them (Kleiner, 2023b).

In the realm of the Möbius strip

The relationship between the modeling object as a fragment of economic space and the mathematical model of this object as a fragment of mathematical space is complex in nature (see *Figure 1*). Similarly, the interactions between mathematics and economics, regarded as two distinct scientific disciplines, are also intricate. The most illustrative representation of these relationships can be achieved by employing the so-called Möbius strip – a non-orientable two-dimensional surface with one side in three-dimensional space. Typically, a long strip of paper is used as a physical model of the Möbius strip, which is glued into a ring after one end has been twisted 180 degrees. This results in a ring where all points can be traversed without crossing the edge of the strip. Since 1976, the Möbius strip has served as the emblem of the Central Economic and Mathematical Institute, symbolizing the integration of economics and mathematics as the primary research directions of the institute (see *Figure 2*). The philosophical significance of the Möbius strip as a model of the surrounding world is linked to the acknowledgment of the unity of the world in both space and time. In the 'Möbius world,' there is no absolute beginning or unconditional end. Throughout cyclical processes, systems alter their forms while retaining the characteristics of their content. This is particularly true for economic systems that regularly implement processes of production, distribution, exchange, and consumption. The same can be said for technological processes that form the foundation of economic development (for a detailed description of the interaction between technological and economic processes, see (Sukhariev, 2025a, 2025b; Kleiner, 2024)).

The concept of the Möbius strip sheds light on one of the fundamental questions of the scientific perspective on the world, specifically regarding the permeability of system boundaries in space and time. In the "Möbius world," the internal content of systems is not separated by an impermeable boundary from the external environment; rather, the internal content and the external environment are in constant interaction and adhere to the laws of duality (for more details, see Kleiner, 2019). This is particularly relevant to the internal content and external environment of systems such as mathematics and economics. The concept of the "Möbius world" somewhat opposes the idea of hierarchical structuring of the economy through its vertical division into mega-, macro-, meso-, micro-, and nano-economics (Kleiner, 2004). The development of the perception of economics as a holistic and even monolithic system holds significant potential for overcoming a range of issues within contemporary economic theory.

In the quest to identify factors that explain the behavior of economic systems in a general sense, it is essential to consider not only microfoundations but also mega-, macro-, meso-, and nanofoundations of various phenomena

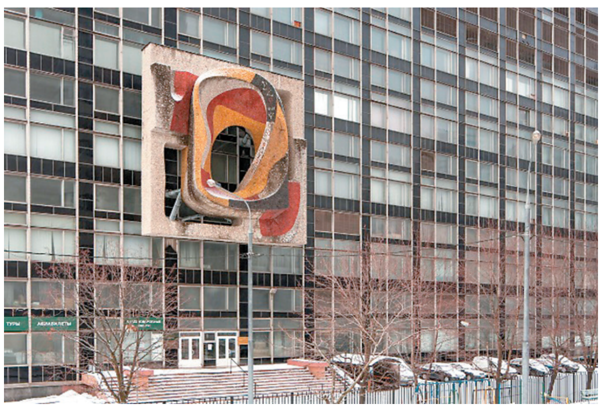

Figure 2. Möbius strip on the facade of the CEMI building

Рисунок 2. Лента Мебиуса на фасаде здания ЦЭМИ or processes. The a priori equality of economic levels as a collection of potential influencing factors, along with the isotropy of economic space – meaning the absence of permanently designated directions of development – forms the basis of a systemic understanding of economics. Such reasoning is equally applicable to different branches of mathematics. The interaction between mathematics and economics, which occurs during the construction of mathematical models for specific segments of the economy or the economy as a whole, is symbolically represented by the Möbius strip. The placement of mathematics and economics on the surface of the Möbius strip illustrates the prospect of a profound symbiosis between these two, generally dissimilar, fields of study.

CONCLUSION

The information presented allows for the following fundamental conclusions regarding the interrelationship between mathematics and economics.

1. Despite the apparent target and functional differences between mathematics and economics as key representatives of fundamental and socio-humanitarian sciences, a detailed analysis reveals common features of both fields that should serve as the foundation for their coordinated and co-evolutionary development.
2. It is essential to encourage not only the expansion of interaction between these disciplines but also the deepening of their methodological interpenetration within the fundamental structure of mathematical and economic perspectives on the world – encompassing both the mathematization of economics and the economization of mathematics.
3. A more comprehensive consideration of the socio-humanitarian and psychological context in the construction and interpretation of mathematical and computational economic models at all levels – from clarifying the meaning of quantitative and qualitative indicators of real phenomena to determining the structure of the domain of permissible and desirable values of key indicators – utilizing the concepts of a modified context-dependent natural series represents a significant reserve for the development of the econometric direction. Consequently, the procedures for constructing and analyzing economic models can be significantly enhanced through the application of knowledge gained from the study of real economic processes and projected onto the algorithms of mathematical analysis of the model. This direction can be viewed as part of the program for developing so-called nature-inspired algorithms.
4. Mathematics and economics are organically situated within the "Möbius space" and should be viewed as part of a unified system of interdisciplinary knowledge about the surrounding world.
5. The advancement of economic-mathematical modeling should be regarded as an interdisciplinary issue within an integral model of the interpenetration of the material and spiritual components of our environment.
6. There exists a unique domain between mathematics and economics where the knowledge of mathematics and economics converges to enhance the understanding of the profound patterns and phenomena of socio-economic reality. "Systemic mathematics," "systemic economics," and "systemic modeling" serve as the three pillars of the process of development, knowledge acquisition, and transformation of the contemporary world.

Competing Interests

The author declares no conflict of interest.

Конкурирующие интересы

Автор заявляет об отсутствии конфликта интересов.

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