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UDC 330.4:37.07

Innovative Economic & Mathematical Modelling for Education Management in Era of Crisis

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Abstract. The article analyzes innovative economic and mathematical modeling as a tool for education management in crisis conditions and under high uncertainty. It is shown that traditional deterministic management models lose effectiveness during large-scale epidemiological, geopolitical, and technological shocks. The study emphasizes a shift toward adaptive and scenario-based approaches focused on system stability and resilience. Education is considered as a complex nonlinear system with delayed human capital effects. The paper substantiates the application of probabilistic methods and agent-based modeling to integrate uncertainty into management decisions and enhance institutional adaptability.

Keywords: education management; economic and mathematical modeling; crisis conditions; adaptive management; uncertainty.

Introduction.

The current phase of the evolution of the socio-economic space is disrupted by increasing entropy and nonlinear dynamics of processes [1]. Classic management paradigms (as well as those in the field of education), which revolve around the extrapolation of retrospective trends and highly deterministic planning, reveal their impossibility when coupled with large-scale exogenous crises (epidemiological, geopolitical and technological) [2-4].

Prote, in a situation where there is a horizon for verifiable forecasting of boundary conditions, there is a strong need for transformation of the management model [5]. The concept of adaptability - the ability of the system to quickly reconfigure the internal architecture and resource base in response to external influences - comes to the forefront [6]. The fundamental tool for implementing such a strategy is promising economic and mathematical modeling [7], [8]. The most innovative economic-mathematical modeling allows us to move from trying to "guess" the future to constructing a polyvariant solution, transforming the insignificance from a destructive official in the field for strategic maneuvering [9].

Results.

The uniqueness of the educational space as an object of formalized economic and mathematical analysis (EMA) is due to its high inertia and a significant time lag between the investment injection and the fixation of the final effect - an increase in the quality of human capital. In the phases of macroeconomic equilibrium, this characteristic legitimizes the use of deterministic tools based on the extrapolation of retrospective series: linear correlations between resource provision and academic performance, as well as strict planning standards, retain their validity.

Nevertheless, the onset of the era of global turbulence and a number of systemic crises (epidemiological, geopolitical, technological) devalue the heuristic potential of the classical EMA methodology. The effect of a "structural shift" is fixed, in which retrospective statistical patterns lose their representativeness in relation to future states of the system. Educational ecosystems demonstrate pronounced nonlinear reactivity: small fluctuations in the external environment are capable of generating cascading intrasystem transformations (from the collapse of demand for individual competencies to the critical erosion of the personnel core), which is beyond the resolution of standard econometrics.

In the current paradigm, the functional role of economic and mathematical modeling undergoes a metamorphosis, shifting from long-term scenario determinism to mechanisms of operational adaptability. The specificity of the updated approach lies in the rejection of the search for the only correct predictive trajectory in favor of assessing the resistance (stability) of the educational structure to stochastic shocks. The key methodological challenge is the incorporation of the uncertainty factor not as "white noise" or statistical error, but as a constituent endogenous variable of the model.

This dictates the need to integrate probabilistic methods that synthesize hard economic constraints (budgetary restrictions, infrastructure costs) with "soft" parameters specific to the pedagogical sphere (dynamics of cognitive patterns, psychosocial climate, qualification-qualification requests of the labor market).

Thus, the imperative of prospective modeling dictates the need to construct dynamic control circuits. These systems must ensure homeostasis and target efficiency of the educational institution at bifurcation points, converting crisis risks into parameters of an updated development strategy.

Architecture of adaptability in modeling.

The key postulate of the proposed approach lies in the shift in focus from the search for a global extremum (efficiency maximization) to ensuring the robotcity (stability) of the system. Instead of static structures, adaptive modeling considers the lighting institution as a dynamic system with the contours of a gateway. The mathematical apparatus here plays the role of a "navigation complex", which ensures continuous recalibration of the development trajectory in order to obtain new signal information from the external environment.

Variable forecasting and damping of risks.

Instead of point predictions, the methodology revolves around a scenario approach. A "tree of possibilities" is generated, which shows the spectrum of possible ways of developing a crisis. This allows you to quantify the economic effects of the skin vector: from fluctuations in the student population and the volatility of budgetary allocations to the need for accelerated digitalization. The model allows the administration to proactively assess the "price" of implementing a skin risk and formulate the necessary reserve buffers.

Microsimulations and agent-based approach.

An essential element of the methodology is agent-based modeling. It allows you to create behavioral patterns of discrete subjects - students, educators, managers. During a crisis period, the actions of actors are often irrational, which does not fit within the framework of classical equalities. Agent-based simulations allow you to protest the reaction of society to management impulses (changes in training formats, revision of the motivation system), identifying latent points of tension and emergent effects to This will manifest itself in physical reality.

Option logic of investment.

Managing resources to achieve turbulence requires rethinking investment strategies through the prism of real options theory. Any initiative (launch of a lighting track, infrastructure project) is treated not as a strict obligation, but as a right to action. Modeling helps to identify optimal time points for scaling successful pilots or, for example, to minimize costs through the ignition of ineffective programs.

Conclusions.

Summary of the analysis, it can be confirmed that the implementation of mathematical forecasting methods to the control circuit of light and the locking of institutional life:

- changing the criteria: the goal function is not to minimize profitability, but to maximize the adaptive potential and survivability of the system;
- proactivity: the model approach will ensure the transition from reactive risk management to preventive risk management;
- resource flexibility: algorithmic reallocation of funds in real time allows you to maintain the capacity of human capital to prevent budget deficits.

Prospects for future research.

The evolution of this problem lies at the level of convergence of econometric methods with technologies for analyzing big data (Big Data) and machine technology. The development of “digital twins” of everyday life will allow for stress testing strategy by computer simulation with a high level of reliability. Promising is the creation of hybrid models [10], synthesizing hard economic metrics with parameters of the psychosocial climate in teams.

Discussions.

There is a continuing debate in the academic community about the limits of the application of formalism in the humanitarian field:

- validity problem: in a crisis, incoming statistical data are often subject to distortions or delays, which actualizes the GIGO principle (“garbage in, garbage out”);
- ethical dilemma: how legitimate is it to delegate decision algorithms that affect people’s fates (human resource optimization, student dropout), even if there is a mathematical justification for “optimality”;
- interpretability: The complexity of model architecture, especially with the use of neural network solutions, gives rise to the problem of a “black box”, reducing the transparency of decision-making logic for stakeholders.

Harmonizing these contradictions requires a cross-disciplinary synthesis of the competencies of economists, mathematicians, sociologists, and experts in the field of AI ethics.

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