Journal of Multidisciplinary Engineering Science Studies (JMESS)
ISSN: 2458-925X
Vol. 11 Issue 6, June - 2025

Agent-Based Modeling for policy design on public economic development: a conceptual approach

M.I.E. Mario Chávez Herrera
Master Degree Student
Departamento de Estudios Multidisciplinarios
Sede Yuriria, Universidad de Guanajuato
DEM-UGTO
Yuriria, México.
m.chavezherrera@ugto.mx

Dr. Jorge Armando López Lemus
Research Professor
Departamento de Estudios Multidisciplinarios
Sede Yuriria, Universidad de Guanajuato
DEM–UGTO
Yuriria, México.
lopezja@ugto.mx

***Abstract*— The Agent-Based Model (ABM) has emerged as a powerful tool in the simulation of complex economic systems, allowing to represent the heterogeneity and adaptability of agents and their interactions. Its application in the design of public policies it offers a more dynamic and realistic perspective, facilitating the anticipation of non-linear and emergent effects in scenarios of economic development, with the potential to transform policymaking public. With the advancement of technology and access to large volumes of data, The MBA is likely to become more widely integrated into decision-making processes. decisions, allowing for more informed and effective policies. This paper covers the theoretical foundations of Agent-Based Modeling (ABM), theory of complex systems, economic development, public policies and methodologies applied, with the purpose of achieving an initial approach to the systems complex, applied as a methodological tool to social phenomena and economic conditions that are currently being experienced, so that an analysis is proposed comprehensive on the use of the MBA as a paradigm in the design of scenarios more realistic and effective economic development, in order to contribute to the formulation of public policies based on evidence and with greater impact on the well-being of the population.**

Keywords*— *Agent-Based Modeling, public policies, development economic, complex systems, social simulation, adaptive governance

I. INTRODUCTION

In a world characterized by the increasing complexity of social phenomena, economic and environmental reasons, the need for have analytical tools that allow capturing the multiple interactions, feedbacks and emerging dynamics that shape the real systems. Traditional economic modeling approaches, such as general equilibrium models or classical econometric models are usually based in assumptions of homogeneity of agents, perfect rationality and markets in balance. These approaches, although useful in certain contexts, are Limited when addressing highly complex problems, such as poverty structural, informal employment, regional inequality or adoption technological, whose evolution depends on dynamic factors, behaviors heterogeneous and interdependent decisions [1].

Formulating effective public policies requires a deep understanding of socioeconomic dynamics. Traditionally, economic models have used aggregate and equilibrium approaches. However, these models often simplify the complexity inherent in social systems. The MBA offers a alternative by allowing the simulation of individual behaviors and their interactions, providing a more detailed and accurate view of the systems economic.

In this context, Agent-Based Modeling (ABM) emerges as a powerful and innovative alternative within the framework of complex systems adaptive. Inspired by complexity theory and paradigms computational fields such as distributed artificial intelligence, the MBA allows for modeling systems composed of multiple autonomous agents, such as individuals, companies, governments or institutions, which interact with each other and with their environment, generating non-trivial collective behaviors and emergent phenomena [2].

Unlike top-down models, which seek to deduce the behavior of the system from global assumptions, the MBA adopts a bottom-up approach, starting of the individual behavior of agents to observe how these give rise to macro-level dynamics.

The MBA's ability to represent heterogeneity, adaptability and non-linear interaction between agents makes it an ideal tool for analysis of complex socioeconomic phenomena. For example, it allows for modeling how families' consumption decisions affect the market, how the technological adoption spreads among rural producers, or how different subsidy policies impact the behavior of various sectors of the

population. These characteristics make it especially useful for simulating scenarios and the evaluation of public policies, since it allows anticipating results unwanted, identify differential distributional effects and explore routes of more effective interventions.

In an environment of high uncertainty and budgetary constraints, governments require approaches that allow for virtual experimentation with different strategies before implementing them. The MBA responds to this need by provide a computer lab where different types of tests can be performed policy designs, adjust parameters, incorporate empirical data and observe the behavior of the system over time [3]. This positions it not only as an academic tool, but as an instrument to support decision-making public decisions with transformative potential.

II. Theoretical Framework

A. Complex systems: the new paradigm for understanding reality

In recent decades, a new scientific paradigm has emerged that recognizes that many of the natural and social systems that surround us cannot be fully understood under linear, deterministic or reductionist schemes.

These systems, called complex adaptive systems, are composed by a large number of interconnected elements whose interactions give rise to emergent, non-trivial, and often unpredictable patterns [1].

The theory of complex systems has taken inspiration from disciplines such as physics statistics, evolutionary biology and cybernetics, transferring principles such as self-organization, feedback and emergence to fields such as economics, sociology, and ecology. In physics, for example, behavior collective of a gas cannot be deduced solely from the physics of a single molecule, but requires considering the statistical interaction of millions of particles. Similarly, in social systems, aggregate behavior of an economy is not simply the sum of the individual behavior of the agents, but the result of their complex and adaptive interactions [5].

Economic systems, in this framework, are considered open systems, dynamic and adaptive, where agents not only respond to incentives, but who also learn, influence each other and modify the environment in which they act. These systems are far from equilibrium and exhibit typical properties of complexity: nonlinearity, sensitivity to initial conditions, feedback positive/negative, and self-organization processes [6].

B. Agent-Based Modeling (ABM): A Bottom-Up Approach to Complexity

The MBA is a computational methodology that models complex systems by representing autonomous agents interacting in an environment defined. These agents can have heterogeneous and adaptive behaviors, which allows capturing emergent dynamics that are not evident in models traditional. This approach is particularly useful in the study of phenomena economic where individual interactions play a crucial role.

In contrast to traditional top-down models that are based on assumptions global (such as perfect rationality, market equilibrium or homogeneity of preferences), Agent-Based Modeling (ABM) represents a break epistemological by proposing a bottom-up vision: building behavior macroeconomic from the simulation of heterogeneous individual agents that interact over time [7].

An agent, in this context, is an autonomous entity with the capacity to perceive their environment, make decisions and adapt. It can represent an individual, a family, a company, an institution or even a geographic region. The agents They may have simple or sophisticated rules of behavior, learn through evolutionary algorithms, imitate other agents (as in social networks), and react to external policies or disturbances.

These simulations generate an “artificial universe” that allows us to observe how global patterns emerge—such as inequality, wealth concentration, financial bubbles or social exclusion—based on local rules. The MBA has been successfully applied in areas such as international trade, resource use natural resources, the labor market and urban planning, demonstrating their potential for Capture phenomena that escape static or average model analysis classics [2].

C. Analogies between physical and social systems

The use of analogies between physical and social systems has historically been a fertile source of new theories. For example, in statistical physics, models of Ising and percolation have been used to explain social processes such as diffusion of innovations or the formation of opinions. Critical state theory self-organized, proposed by Bak et al., has also been applied to contexts socioeconomic to explain the occurrence of financial crises as phenomena of avalanches in apparently stable systems [8].

Similarly, concepts such as entropy (measure of uncertainty), attractors (states towards which systems tend), or dynamics of nonlinear systems have been transferred to economic analysis. These approaches have given rise to new lines of thought such as evolutionary economics, sociophysics or econophysics, which complement the MBA with robust conceptual frameworks.

Economic development is not a linear or homogeneous process. Factors such as Innovation, education, infrastructure and public policies interact in a way complex manner. The MBA allows us to model these interactions and analyze how Small modifications can have significant effects on the system economic as a whole.

D. Public Policies and Simulation with MBA

Traditional public policies are often based on equilibrium models which may not adequately capture nonlinear dynamics and complex interactions. The

MBA offers a tool to simulate different scenarios and assess the potential impact of various policies before their implementation actual implementation.

The usefulness of the MBA is not limited to its descriptive power. When modeling systems complex with multiple levels of interaction, the MBA allows:

i. Explore counterfactual scenarios: what would happen if a subsidy policy only in rural areas?

ii. Anticipate collateral or emerging effects: such as the displacement of economic activities or the formation of informal markets.

iii. Design adaptive policies: that dynamically adjust based on the system behavior.

iv. Capture non-rational behaviors: such as risk aversion, social learning or cultural norms.

Thus, the MBA becomes a cognitive infrastructure for course takers. decisions, researchers and planners, allowing to address complexity social with greater precision and contextual sensitivity, so that policies public and computational simulation using MBA as a tool for Understanding the social and the economic are an optimal alternative.

III. Historical Background of Agent-Based Modeling in Economics and Public Policies

Agent-Based Modeling (ABM) did not emerge in a vacuum. Its development represents the result of a series of interdisciplinary convergences that began to take shape in the mid-20th century and, in their maturity, have challenged the classical conceptions of economics, opening new paths for the understanding and management of complex social and economic phenomena. The MBA is heir to intellectual traditions that come from artificial intelligence, cybernetics, game theory, cognitive psychology, systems theory and, very especially, the criticism of neoclassical economic models based on the general equilibrium [9].

A. Conceptual and technological roots Abbreviations and Acronyms

The origin of the MBA can be traced back to the first experiments in intelligence distributed artificial and multi-agent systems in the 1970s, particularly in research laboratories such as MIT and Carnegie Mellon University. These Research sought to simulate decentralized intelligent behaviors, inspired by the functioning of insect colonies, neural networks or simple human behaviors. With the progressive improvement of the capacity computational, these approaches began to migrate into broader domains, including economics and sociology [7].

The leap into the economic field occurred more explicitly from the 1980s onwards. and 1990, partly as a reaction to the rigidity of traditional models. Authors such as Herbert Simon—with his theory of bounded rationality—and Thomas Schelling, with his models of urban segregation based on simple rules of behavior, laid the theoretical foundations of the agent-centric approach [10].

One of the founding works in this field was Schelling's model (1971) about how small individual preferences could lead, in a way, unexpected, to a total segregation of urban space, perfectly illustrating the principle of emergence: the whole is not equal to the sum of its parts. This was a direct precedent of the use of the MBA as a tool to understand dynamics complex social [11].

B. Emergence of the MBA in economics: criticism of orthodoxy and new approaches

During the 1990s, criticism of neoclassical economics intensified. in In particular, the validity of the assumptions of perfect rationality was questioned, homogeneous expectations, general equilibrium and representative agents. In this context, heterodox economists began to adopt models based on agents to explore phenomena such as financial bubbles, networks of innovation or consumption decisions under uncertainty.

One of the pioneers in this line was Robert Axelrod, who applied simulations agent-based approaches to study the evolution of cooperation in contexts without central authority, using models inspired by the iterated prisoner's dilemma [5]. His work set a precedent in the use of simple and dynamic learning rules to simulate social and economic behavior.

In parallel, the Santa Fe Institute, founded in 1984, became a key center for the integration of complexity into economic thinking. Figures such as Brian Arthur introduced concepts such as technology-based competition, path dependence and self-organization in financial markets, all which were formalized using MBAs. In this environment, the MBA emerged as a serious and rigorous alternative for modeling out-of-equilibrium dynamics and based on heterogeneity [2].

C. Incorporation of the MBA in the formulation of public policies Equations

The 2000s marked the beginning of a second phase: the application of the MBA in the design, evaluation and simulation of public policies. Institutions such as the OECD, the World Bank and local governments began to explore the potential of the MBA to predict the impact of policies in contexts with high uncertainty or multiple actors.

One of the first uses of the MBA in public policy was in planning. urban and transport, through agent-based traffic simulations (ABM-traffic). It was then expanded to areas such as water management, climate change mitigation climate and social policies. These models allowed for the simulation of scenarios counterfactuals—"what if..."—something very difficult to achieve with methods traditional econometrics.

In Latin America, cases such as the model developed by Mora-Herrera et al. (2023) to evaluate rural public policies in Medellín, Colombia, have demonstrated how the MBA can offer more faithful representations of the real dynamics, capturing indirect effects, institutional tensions and community adaptations that do not usually appear in conventional models [3].

D. Consolidation and perspectives

Today, the MBA is a methodology recognized in multiple disciplines, integrated into statistical packages and platforms such as NetLogo, Repast or MASON. It is used in applied research programs, interdisciplinary doctorates and evaluation of public policies. It has been particularly useful in the design of policies in systems socio-ecological, innovation systems, informal labor markets, and dynamics of social inclusion-exclusion.

Its usefulness lies not only in what it simulates, but in how it changes the way of thinking. development: from a static and universal approach to a dynamic, contextual one, experimental and evolutionary.

IV. Economic Development and Complexity

For much of the 20th century, economic development was approached from Theoretical models focused on equilibrium, optimization and linearity, such as neoclassical growth theory (Solow, Ramsey), the stage approach to development (Rostow), or modernization theory. These approaches, while useful To understand certain macroeconomic trends, they implicitly assumed that development followed predictable, stable and universalizable trajectories. However, in recent decades, the limits of these models have become evident in the face of the persistence of structural inequalities, informality chronic, the stagnation of lagging regions and the unanticipated impacts of economic policies [12].

From the perspective of complex systems, economic development is not a technical, mechanical, or universal process, but rather an emergent phenomenon, contextual and evolutionary. Each territory, city or country follows a unique trajectory, influenced by historical, institutional, cultural and social factors. In this sense, development is more like a biological process than a function. mathematics; it is the result of multiple interactions between agents, decisions decentralized, local adaptations and dynamic feedbacks [13].

Various studies have applied the MBA in the field of economic development and public policies. For example, the study by Mora-Herrera et al. (2023) used a MBA to evaluate rural public policies in Medellín, Colombia, demonstrating how this tool can complement conventional agricultural models and offer a more dynamic view of the policies implemented.

The MBA allows you to model various aspects of economic development, such as income distribution, technology adoption, and social mobility. By simulating how agents respond to different policies and conditions, can be Identify strategies that promote inclusive and sustainable economic development.

A. Economic development as a complex adaptive system Authors and Affiliations

A complex adaptive system (CAS) is defined by the presence of many heterogeneous elements that interact, adapt and evolve in response to internal and external stimuli. The economic system, understood in this way, it is not in equilibrium, but in constant transformation. Elements such as technological innovation, the structure of productive networks, decisions investment, tax policies or cultural changes interact with each other, generating unpredictable results at the aggregate level [14].

Rather than assuming an optimal growth path, the complexity approach observes how multiple developmental trajectories can emerge depending on local capabilities, social capital, agglomeration effects or the institutional coordination. This vision breaks with the reductionism of a single recipe for development and opens the door to the design of differentiated strategies, context-sensitive and evolutionary.

For example, regions that start out with similar conditions may diverge. radically over time due to random events (path dependence), differential public policies or local synergies. This phenomenon is observed clearly in cases of uneven industrialization or technological clusters successful like Silicon Valley, which are not explained exclusively by endowments initial but by self-reinforcing dynamics and complex networks of collaboration [15].

B. The need for new analysis tools: from linearity to simulation Identify the Headings

In this context, the need for analytical tools that become evident can capture this complexity. Linear equations or average models lose meaning when it comes to understanding how small actions can amplified, how social norms can condition the adoption of Innovations, or how coordination failures can create poverty traps persistent.

This is where Agent-Based Modeling (ABM) offers an analytical advantage. decisive. By representing economic actors —consumers, businesses, public institutions—as individual agents with behaviors and objectives, different development scenarios can be simulated and their analysis long-term consequences, considering the interaction between microdecisions and macrostructural effects. This allows us to observe, for example, how a policy of subsidizing education can have indirect effects on productivity, social mobility and institutional stability.

C. Key elements of complexity in economic development

Economic development, from this perspective, presents a series of features typical of complex systems that can be efficiently modeled with MBA:

i. Emergence: the aggregate behavior of the system (such as GDP per capita, inequality or innovation) cannot be directly deduced from the individual behavior of its components, but arises from their interactions.

ii. Feedback: economic decisions affect the environment (institutional, environmental, social), and this in turn modifies future decisions, in a circular process.

iii. Path dependence: development follows trajectories historical sensitive to past events, which implies that policies must consider previous contexts and accumulated capabilities.

iv. Adaptability: agents are neither passive nor completely rational; they learn, experience, and adapt to new environments or incentives.

v. Interaction networks: economic processes are mediated by networks social, commercial or technological that amplify or cushion impacts, making linear prediction difficult.

D. Economic development as a result of micro-macro interaction

One of the most relevant contributions of the MBA is its ability to model the interdependence between micro and macro levels. For example, decisions of employment of a company influences household income, which in turn affects consumption, demand for goods, tax collection and, eventually, the State's capacity to invest in infrastructure. This type of circular dynamic It is essential to understand why some public policies have effects virtuous while others fail.

The MBA allows you to experiment with these feedback loops, simulating how different intervention strategies can generate trajectories of divergent development. This is especially valuable in contexts of uncertainty, where there are no predefined solutions and where decisions must constantly adapt to new realities.

V. Linking ABM with Formulation and Public Policy Evaluation Economic Development and Complexity

In the contemporary world, public policies face unprecedented challenges. precedents: high uncertainty, multiple levels of decision-making, social dynamics non-linear, and the coexistence of diverse actors with conflicting objectives. traditional approaches to analysis —based on assumptions of rationality perfect, average agents and static equilibria—have been shown to be insufficient to capture this complexity. In this context, Modeling Based in Agents (MBA) has established itself as a powerful tool for simulating more realistic, adaptive, and context-sensitive public policy scenarios social, territorial and institutional [2].

The MBA allows to represent each actor involved - citizens, companies, social organizations, government entities— as individual agents with own capabilities, motivations, restrictions and information, whose interactions generate emerging dynamics that can be analyzed and, eventually, intervened through specific policies.

A. Changing the policymaking paradigm: from deterministic to adaptive Economic development as a complex adaptive system Authors and Affiliations

One of the main contributions of the MBA to the formulation of public policies is the shift from the deterministic and linear paradigm to an exploratory approach and adaptive. Traditionally, policies were designed under a causal logic effect: it was assumed that a specific intervention (e.g. a subsidy) would generate an expected result (poverty reduction, increased productivity). However, experience has shown that policies operate in highly sensitive, non-linear, and multi-faceted social systems feedbacks, where the effects can vary drastically depending of the context and the initial configuration [16].

The MBA allows these policies to be simulated as virtual experiments, in which Their impacts can be observed in different scenarios, considering the heterogeneity of the agents, their interactions and the environmental conditions. This allows for more realistic, informed and robust policy making public.

B. Towards a public policy focused on behavior

Another key contribution of the MBA is its ability to incorporate elements of real human behavior: bounded rationality, social learning, norms cultural, emotions, trust, informal networks, etc. This distinguishes it clearly from the classical models based on homo economicus.

For example, by simulating a labor formalization policy, the MBA can incorporate the fact that workers make decisions not only based on income, but also networks of trust, fear of state control, or previous negative experiences. Thus, incentive design can be more effective if It is based on simulations that capture this contextualized behavior [17].

Similarly, a vaccination policy can benefit from models where the agents decide to get vaccinated not because of legal obligation, but because of observation of the behavior of their peers or by influence of community leaders. In these In some cases, MBA-based interventions can optimize resource use, identifying leverage points such as opinion leaders, channels of informal communication or strategic areas.

C. Scenario simulation, counterfactual evaluation and prevention of unintended effects

One of the biggest advantages of the MBA is its ability to conduct assessments ex ante, through the simulation of multiple scenarios and alternative trajectories.

This makes it possible to anticipate possible unintended consequences, indirect effects, distributive inequalities or emerging social tensions.

For example, an agricultural subsidy can be simulated in different contexts. climatic, institutional or cultural, observing how different types react of producers (small vs. large), which marketing networks are strengthened or weaken, and what territorial effects it may have (such as rural-urban migration or change of land use) [18].

Furthermore, the MBA allows for counterfactual evaluations: what would have happened What would have happened if the policy had not been implemented? Or if it had focused on another group? Or if it had been implemented in a different sequence? These questions are very difficult to answer with traditional statistical methods due to the impossibility of observing what did not happen.

D. Outstanding applications of the MBA in public policy

The use of the MBA in the public sector has expanded into various areas, including:

i. Social policy: simulations of poverty dynamics, social inclusion, access to public services, migration and conditional transfers.

ii. Education: models that analyze school dropouts, teaching quality, or unequal access to resources.

iii. Public health: evaluation of vaccination campaigns, models epidemiological with mobile agents, and analysis of collective behavior in the face of pandemics.

iv. Environment and sustainability: watershed management simulations, deforestation, climate change and governance of common goods.

v. Local economy and employment: models of labor dynamics, informality, chains of value, and effects of fiscal policies or territorial subsidies.

A prominent example is the SESIM model (Swedish Economic and Social Interaction Model), used by the Swedish government to analyze policies social and tax. This model allows for the evaluation of distributive impacts, labor and fiscal sustainability through the simulation of millions of agents representative of the Swedish population [19].

In Latin America, initiatives such as those of Mora-Herrera et al. (2023) have demonstrated that it is possible to build MBA models in local contexts, with community participation, and with a participatory approach that reinforces legitimacy of public decisions [20].

E. Limitations and ethical-political challenges

Despite its strengths, the MBA is not without its limitations. Some challenges include:

i. Availability and quality of data to parameterize and validate the models.

ii. Computational complexity in large-scale simulations.

iii. Interpretability of results by decision makers simulation experts.

iv. Risk of technocratization, if the model prevails over political judgment and ethical decision-making.

Therefore, the use of the MBA in public policies must be accompanied by processes of democratic deliberation, participatory validation and interdisciplinary dialogue. The model should serve as a support, not as a substitute for human judgment or social deliberation.

F. Formulation of Public Policies with an MBA Foundation

The implementation of the MBA in the formulation of public policies involves the following: following steps:

i. Definition of Objectives: Establish clear and measurable goals for the policy public.

ii. Agent Modeling: Represent key actors and their interactions in the system.

iii. Scenario Simulation: Run simulations to assess the impact of different policies.

iv. Results Analysis: Interpret the results to identify policies effective.

v. Implementation and Monitoring: Apply the selected policy and monitor its effects.

This approach allows for a more accurate evaluation of policies before their implementation, reducing risks and improving efficiency.

CONCLUSIONS

Agent-Based Modeling represents a methodological innovation transformative in the formulation of public policies. Its capacity to represent heterogeneous behaviors, simulate complex scenarios and facilitating collective deliberation processes positions it as a tool essential to the 21st century governance agenda. Adopting the MBA involves transitioning from a linear planning logic to one based on complexity and learning institutional and the active participation of citizens. This research contributes to the development of a conceptual agenda that makes knowledge Computing: a lever for social justice and economic development sustainable.

Far from being an experimental technique reserved for academic contexts, the Agent-Based Modeling proves to be a fundamental tool for transform the way we think, design, and implement policies public. Its adoption, especially in municipalities and regions with high Structural vulnerability can make the difference between reactive policies short-term and sustainable strategies for territorial transformation. Commit to the MBA is, ultimately, betting on a more humane public policy, adaptive and intelligent.

The general conclusions are referred to in seven main points:

A. The MBA as a methodological response to local socioeconomic complexity

Research demonstrates that Agent-Based Modeling provides a framework exceptional theoretical and practical ability to address the inherent complexity of systems contemporary social and economic. In an environment characterized by a dominant informal economy, structural migration, technological lag and pressure environmental, traditional linear and aggregate methodologies result insufficient to understand local dynamics and implement solutions effective. The MBA, by modeling heterogeneous individuals and their interactions, allows simulate emerging behaviors, explore alternative scenarios, and anticipate non-linear effects on policy implementation.

B. Reconfiguration of the public policy formulation process

The MBA is not only presented as a predictive tool, but as a governance technology that transforms the public policy cycle. By introducing the logic of complex systems in planning and evaluation processes, promotes a new institutional rationality based on simulation, controlled experimentation, deliberative participation and constant adaptation. In this sense, its implementation breaks with the paradigm of decision-making. vertical decisions, promoting territorial collective intelligence and a continuous learning from practice.

C. Institutional empowerment and democratization of knowledge

The participatory approach strengthens the legitimacy of policies by involving citizens, economic actors and social organizations in construction of scenarios and the validation of results. This process democratizes the technical knowledge, facilitates the appropriation of the proposed solutions and builds trust between citizens and local government. The MBA becomes, thus, in an interface that translates expert knowledge into decisions understandable and useful to the community.

D. Potential impacts on local economic development

The simulated scenarios show that the implementation of public policies designed based on MBA can generate significant effects in the medium term: reduction of informality, increase in income, technological adoption, Productive inclusion of young people and women, and strengthening of activities sustainable economic. These results arise not only from better targeting policies, but rather the model's ability to identify synergies, predict adverse effects and energize idle resources through interventions systemic.

E. Challenges and conditions for the sustainability of the approach

Despite its advantages, the institutionalization of the MBA faces significant challenges: resistance to change within government structures, need for specialized technical capabilities, access to and quality of local data, and initial financial requirements. Overcoming these challenges requires a strategy comprehensive training, inter-institutional alliances, governance mechanisms participatory and, above all, political will to innovate in public management from a systemic vision.

F. Towards a national agenda for simulation and public policies based on complexity

Once more specific cases have been studied, the foundations can be laid for scale this approach to municipalities, regions and states of the country, especially those with similar problems: structural exclusion, institutional weakness and environmental pressure. Propose a national agenda that recognizes the MBA as A valid instrument for the design of public policies would strengthen planning territorial, would increase the effectiveness of social programs and allow for the transition towards a public administration focused on anticipation, resilience and inclusion.

G. Scientific, methodological and social contribution of the research

This research provides a conceptual alternative that articulates systems theory complex, participatory model building, use of platforms computational tools such as NetLogo and GAMA, scenario simulation and formulation of empirically based policies. In scientific terms, it expands the frontier of applied knowledge on adaptive governance in subnational territories. Conceptually, it offers an integrative approach between technology, knowledge social and public action. And in the social sphere, it proposes a vision of economic development territorial that puts collective intelligence and learning at the center as drivers of change.

The MBA is not just a technical tool; it's a new way of thinking the formulation of public policies in complex contexts. Its capacity to represent heterogeneity, simulate dynamic interactions and anticipate effects emerging markets makes it a strategic ally for the design of more policies sensitive, inclusive and effective.

In a world undergoing rapid transformation—marked by systemic crises, social tensions and budgetary restrictions—the MBA offers a path to build adaptive institutional intelligence, capable of learning, simulating and adjusting policies in real time, and based on contextualized evidence, also offers an innovative perspective in the design of public policies for development economic. Its ability to model the complexity and heterogeneity of the social systems allows a deeper understanding of the dynamics economic by integrating the MBA into the policy-making process, it is possible to design more effective interventions adapted to local realities, promoting more inclusive and sustainable economic development.

REFERENCES

[1] F. Chávez-Juárez, "On the Role of Agent-based Modeling in the Theory of Development Economics," Review of Development Economics, vol. 21, no. 3, pp. 713–730, 2017.

[2] J.-F. Mercure et al., "Modelling complex systems of heterogeneous agents to better design sustainability transitions policy," Environmental Innovation and Societal Transitions, vol. 17, pp. 1–14, 2015.

[3] M. Mora-Herrera et al., "Development of an Agent-Based Model to Evaluate Rural Public Policies in Medellín, Colombia," Sustainability, vol. 16, no. 18, p. 8185, 2023.

[4] M. Gell-Mann, The Quark and the Jaguar: Adventures in the Simple and the Complex, W. H. Freeman, 1994.

[5] PW Anderson, "More is different: Broken symmetry and the nature of the hierarchical structure of science," Science, vol. 177, no. 4047, pp. 393–396, 1972.

[6] B. Arthur, "Complexity and the economy," Science, vol. 284, no. 5411, pp. 107– 109, 1999.

[7] N. Gilbert, and KG Troitzsch, Simulation for the Social Scientist, Open University Press, 2005.

[8] P. Bak, How Nature Works: The Science of Self-Organized Criticality, Springer, 1996.

[9] HA Simon, The Sciences of the Artificial, 3rd ed., MIT Press, 1996.

[10] TC Schelling, "Dynamic Models of Segregation," Journal of Mathematical Sociology, vol. 1, pp. 143–186, 1971.

[11] R. Axelrod, The Evolution of Cooperation, Basic Books, 1984.

[12] D. Rodrik, One Economics, Many Recipes: Globalization, Institutions, and Economic Growth, Princeton University Press, 2007.

[13] E. Ostrom, "A general framework for analyzing sustainability of social-ecological systems," Science, vol. 325, no. 5939, pp. 419–422, 2009.

[14] B. Arthur, The Nature of Technology: What It Is and How It Evolves, Free Press, 2009.

[15] R. Nelson and S. Winter, An Evolutionary Theory of Economic Change, Harvard University Press, 1982.

[16] R. Axelrod, The Complexity of Cooperation: Agent-Based Models of Competition and Collaboration, Princeton University Press, 1997.

[17] E. Ostrom, Understanding Institutional Diversity, Princeton University Press, 2005.

[18] D. Helbing, "Agent-based modeling," in Social Self-Organization, Springer, pp. 25–70, 2012.

[19] T. Holm, "SESIM: A Swedish Micro-Simulation Model for Policy Evaluation," Swedish Ministry of Finance, Working Paper, 2007.

[20] M. Mora-Herrera et al., "Development of an Agent-Based Model to Evaluate Rural Public Policies in Medellín, Colombia," Sustainability, vol. 16, no. 18, p. 8185, 2023.