

Preface

Socio-economic sciences are undergoing a great conceptual change. Little by little economists and sociologists have started to understand the need to introduce new and more sophisticated mathematical models in their fields of study. New quantitative approaches are required: models that merge mathematics and physics on the one hand, and economics and sociology on the other hand, have proven to be useful in explaining phenomena of the complex world we live in.

This monograph goes in such a direction: it aims at developing a mathematical approach toward the modeling of socio-economic systems, composed of a large number of interacting agents, both in the case of spatial homogeneity and on networks. The contents focus on living complex systems, for which the derivation of mathematical tools requires tackling several difficulties arising along the following conceptual path:

- Identification of the main complexity features that characterize the systems under consideration. The first consequent step is developing a strategy for representing the state of the system, with the aim of reducing the global complexity while keeping, however, the distinctive features.
- Derivation of mathematical structures suitable for describing, via properly specified mathematical models, the evolution in time of the variables selected for representing the state of the system.
- Modeling of specific socio-economic systems on the basis of a phenomenological interpretation of the microscopic interactions among the composing entities. This step may involve multiscale issues.
- Validation of models by investigating their ability to depict emerging behaviors observed in real systems. In some cases, models may even describe trends not yet revealed by empirical data, thereby suggesting new perspectives for interpreting the genesis of emerging behaviors.

This project calls for the development of new mathematical tools. In this monograph we specifically refer to the approach by the kinetic theory for active particles, KTAP for short, which has already been applied to various fields of life sciences and social sciences. It has been proven that the mathematical structures that

formalize this theory include, as particular cases, some well known models of the kinetic theory for classical particles. The main difference here is that interactions among particles are described as stochastic games rather than by deterministic causality principles (analogous to the laws of classical mechanics).

This monograph has three parts. The first part, encompassing Chaps. 1 and 2, is devoted to methodological insights into the complexity features of socio-economic systems and to the derivation of mathematical modeling tools. The second part, encompassing Chaps. 3 and 4, focuses on applications. The third part, consisting of Chap. 5, offers a critical analysis and looks forward at to research perspectives, including the application of the proposed methods to a large variety of social systems. In more detail, chapter contents are as follows:

Chapter 1 presents the aims of the monograph and provides an assessment of relevant complexity features of living systems in general, and social systems in particular. One of the main features is the ability of interacting entities to express behavioral strategies, which are modified according to the state and strategy of other entities. Next, the chapter offers a concise literature survey of modeling approaches, particularly those that are close to the cultural context of this monograph.

Chapter 2 deals with the derivation of mathematical structures, which can act as a background paradigm for the subsequent construction of models. It shows how complex systems can be properly represented by suitable variables, some of them directly related to the aforementioned expression of a behavioral strategy, and thereby described in a probabilistic/statistical way by means of distribution functions over such variables.

Chapter 3 applies the mathematical tools derived in Chap. 2 to the dynamics of social competition in nations. Social interactions can modify the distribution of wealth among the individuals according to both cooperative and competitive strategies. Such interactions can be partly controlled by welfare policies, so a goal of mathematical modeling is predicting the large-scale consequences of the latter. A hallmark of the proposed model is that microscopic dynamics are modeled by nonlinearly additive interactions.

Chapter 4 develops various simulations, which explore prototypical scenarios of welfare policy. Simulations aim at both a parameter sensitivity analysis and assessing the effect of different actions of a hypothetical government on the dynamics of wealth redistribution. This detailed analysis contributes to the necessary background for the developments proposed in the last chapter.

Chapter 5 is devoted to research perspectives concerning both modeling and analytical issues. More precisely, it discusses possible generalizations of the modeling approach presented in the preceding chapters to a variety of different social contexts; for instance, opinion formation related to political competition for leadership, which can be fostered by both communication among individuals and external actions, including some aspects of interactions on networks. Finally, it critically analyzes the contribution of mathematics to social sciences, having in mind the ambitious goal of constructing a mathematical theory of social systems. We hope this forms a useful prelude to the future development of the monograph into an exhaustive book.

All chapters are concluded by a critical analysis, proposed with a twofold goal: focusing on developments needed for improving the efficacy of the proposed methods, as well as envisaging further applications, possibly in fields different from those treated in this monograph.

Paris, France
Torino, Italy
Rome, Italy

Giulia Ajmone Marsan
Nicola Bellomo
Andrea Tosin

Complex Systems and Society

Modeling and Simulation

Bellomo, N.; Ajmone Marsan, G.; Tosin, A.

2013, XII, 90 p. 12 illus. in color., Softcover

ISBN: 978-1-4614-7241-4