Preface

IN THE LAST DECADE of the last century and over the course of the current one, several scientific publications have emerged that seek to disseminate a conception of the world based on the 'vision of complexity' [e.g., Miller, 2016; Holland, 2014; Ball, 2012 and 2004; Mitchel, 2009; Johnson, 2007; Miller and Page, 2007; Buchanan, 2007 and 2002; Johnson, 2001; Gell-Mann, 1995; Waldrop, 1992]. These books do not focus on a particular discipline; on the contrary, they argue that the collective phenomena of social and natural environments can be modelled and understood under certain universal premises. Among these, one stands out: the fact that aggregate behaviours are a result of the interdependence that exists between the heterogeneous agents of a system – which operate based on relatively simple rules conditioned by a particular environment (or structure). In this way, it is possible to explain the flight of a flock of birds, the temperature of any material, human settlements, electoral results, and market dynamics, among many other phenomena.

This book goes beyond the objective of science popularisation. It presents a relatively detailed explanation of the paradigm of complexity in the context of socioeconomic phenomena and expounds upon different methodologies in order to formulate hypotheses that are susceptible to external validation (i.e., empirical verification). In addition to exploring the semantics of the paradigm and showing to the reader some of the computational models used to describe real world observations, the text develops a meta-theory that allows the vision of complexity to be framed within the context of social research. This paradigm, like any other, requires a meta-theory that provides a

wide-ranging analytical scaffolding within which to construct theories and hypotheses about particular phenomena.

The meta-theory elaborated here arises from a process of questioning the axiomatic premises of the neoclassical approach, traditionally taught in economics departments and faculties. For this reason, it is useful for the reader to have a certain degree of knowledge about the assumptions and methodologies adopted by conventional theories of economic thought. Likewise, the language of the explanations and the way in which the arguments are articulated make it essential that the reader has relatively developed skills of reflection and abstraction. Although the book makes use of concepts, arguments and methodologies that may be considered "state of the art", it is not an advanced text. This is because the expounding of the different topics is not carried out in depth. Nor is it required that the student have the mathematical and programming skills needed to build computer models.

Given all the above, the book has four different objectives: 1) To convince the reader that there exist research paradigms with postulates that differ from those of neoclassical economics, but which make use of equally rigorous methods. 2) To introduce the vision of complexity, its semantics and methods of analysis. 3) To undertake a synthesis of different approaches to economics (e.g., behavioural, evolutionary, institutional), and analytical sociology in order to develop a meta-theory. 4) To demonstrate, using simple models, how this vision and the associated methods can be applied to the study of diverse phenomena of a social nature.

Readership to whom this book is addressed

The text was written with the idea of influencing the formation of economics students. Hence, the book references problems that are studied in this discipline and contrasts the theories of complexity with those derived from the neoclassical paradigm. Nonetheless, the examples, arguments and modelling techniques developed here can be extremely useful for students and researchers in any other area of the social sciences, in particular for those who have an interest in learning about a novel approach to the formulation and corroboration of hypotheses.

One of the great virtues of the vision of complexity is the universal perspective that it offers for analysing phenomena of a very diverse nature. The recurrent critique

made of social scientists – that they fragment the knowledge of collective phenomena that emanate from human activity – can be addressed via this paradigm. This is because the premises of this vision are usually attractive to social researchers from different disciplines. Likewise, models elaborated under this perspective provide the possibility of integrating theories that link micro-behaviours and their interactions with macroscopic phenomena of various kinds [Squazzoni, 2012]. As more social researchers come to share a common language and make use of methodologies characteristic of a systemic approach, the fruit of transdisciplinary work will be observed more frequently.

Given the language of the present work, sophisticated knowledge in economics, mathematics, statistics or computation is not required in order to understand the relevant explanations. However, it is advisable that the reader have previously studied an intermediate-level book in microeconomics and econometrics. Readers with a good foundation in economics will more easily be able to assimilate the explanations offered and appreciate the epistemological benefits of the paradigm of complexity with respect to conventional theories. In light of this, the text can be considered accessible to undergraduate students in advanced semesters, graduate students and social researchers; especially those who are willing to venture out onto methodological paths which, although not yet fully explored, have the potential to generate knowledge about different social problems that, to date, have not been adequately addressed.

Different fragments of this book have already been used for courses in intermediate microeconomics, advanced microeconomics, dynamic systems, game theory, public policy, social complexity and computational social sciences. Parts of the text have also been applied in the instruction of curricular subjects in disciplines such as economics, sociology, demography, urbanism, international relations, political science and public administration. The current version is the product of a sequence of preliminary manuscripts used in courses and workshops offered by the following Mexican academic institutions: *Tecnológico de Monterrey* (ITESM), *Centro de Investigación y Docencia Económica* (CIDE), *El Colegio de México* (COLMEX), *Facultad Latinoamericana de Ciencias Sociales* (FLACSO), *Universidad de las Américas-Puebla* (UDLAP), *Benemérita Universidad Autónoma de Puebla* (BUAP) and *Universidad Popular Autónoma del Estado de Puebla* (UPAEP).

Structure of the book

The book is comprised of 21 chapters, in which the study of socioeconomic phenomena conceived as collective behaviours of complex adaptive systems is addressed. The first four chapters act as a succinct introduction to the paradigm, presenting a critique of orthodox thinking in economics, the vision of complexity, and several examples of complex systems in natural and social environments. Chapters 5-7 introduce the semantics of the paradigm, describe the pillars on which this vision is constructed, and explain the most basic models of agent-based simulation (cellular automata).

Chapters 8-11 develop a meta-theory, with the purpose of analysing social phenomena through the lens of complexity. This meta-theory acquires its distinctive features from formulations developed in analytical sociology and in behavioural, institutional and evolutionary economics. This part of the book focuses on characterising the set of factors that affect human agency (or people's ability to learn, decide and act), the structure within which individuals are socially embedded, and the co-evolutionary processes of agency and structure. Chapters 12-16 review certain methodological aspects in order to build computational agent-based models, such as cellular automata, virtual societies with mobile agents, static network models, dynamic network models, and diffusion dynamics models in static networks.

Chapters 17 and 18 introduce algorithmic models to describe learning processes in environments containing a certain degree of uncertainty, whether these processes are carried out at individual or social level. Chapters 19 and 20 present different formal methods for the external validation (empirical calibration and replication of statistical regularities), and internal validation (consistency and error detection) of computational models. In addition, it is highlighted that the replication and selection of these models is essential so as to allow theories that have not been empirically refuted to form part of the knowledge pool. The book concludes with chapter 21, which briefly outlines three empirically validated models that have had some resonance in the community of academics engaging with social complexity: one of a macroeconomic nature, another on the economic development of countries and regions, and a third more related to electoral processes.

Recommended courses for the book and suggestions for supporting material

Several chapters of this textbook can be used as part of the agenda of traditional courses in microeconomics, behavioural economics, macroeconomics, finance, history of economic thought, game theory, analytical sociology, political theory, social network analysis and research methodologies in the social sciences. The material can be covered in its entirety in two courses (of 48 class-hours each) on social complexity created purposely for an undergraduate or graduate degree. Although the book can be read without previous knowledge of programming – in which case it is sufficient to review the simulations – the study of the topics it contains becomes much more attractive when accompanied with laboratory sessions on learning to program in *NetLogo* [hyperlink 0.1]. If the latter is the case, the following books are recommended as supporting material:

1 *An Introduction to Agent-Based Modeling. Modeling Natural, Social, and Engineered Complex System with NetLogo* by Uri Wilensky and William Rand [0.2], which, in addition to teaching how to program in *NetLogo*, introduces different practices for the construction and validation of agent-based models. It should be noted that the first of these authors is the main developer of *NetLogo*.

2 *Agent-Based and Individual-Based Modeling: A Practical Introduction* by Railsback and Volker Grimm [0.3], written in a very didactic way, with a website containing supplementary material. This text also presents a protocol (ODD), widely used in scientific publications, to describe agent-based models.

3 *Introduction to Agent-Based Modelling* by Marco Janssen [0.4], which presents brief explanations and very simple examples to teach programming. Professor Janssen is one of the promoters of an internet portal that brings together a wide network of researchers, educators and professionals interested in the development and use of agent-based models in the social and ecological sciences: CoMSES Net / Open-ABM [0.5].

4 *NetLogo: A Modeling Tool* by Juan Carlos García and Fernando Sancho [0.6], written in English and Spanish. While the text is very accessible to students without previous training in programming, it simultaneously deals with advanced topics pertaining to the platform and language.

5 *Agent-Based Spatial Simulation with NetLogo. Volumes 1 and 2* edited by Arnaud Banos, Christoph Lang, and Nicolas Marilleau [0.7], which provide basic and advanced concepts of *NetLogo*, with an emphasis on spatial simulations and tools for exploring the results generated by computer models.

If the reader prefers to rely on lessons taught by a lecturer, it is advisable that they consult Gabriel Wurzer's tutorials, available on YouTube [0.8], or follow the course 'Introduction to Agent-Based Modelling' taught by William Rand, whose videos can be found on the *Complexity Explorer* page of the Santa Fe Institute [0.9]. For the reader interested in reviewing some simple models on economic issues developed in *NetLogo*, they are recommended to consult the book *Agent-Based Modelling in Economics*, by Hamill and Gilbert, which can be downloaded from the electronic portal of the former [0.10].

In addition to each chapter's central contention, the text contains a series of textboxes whose reading can be omitted without detriment to the explanations. These boxes aim to reinforce the student's learning, either because they describe the way in which certain models work, revise the concepts and theories that should form part of the reader's background knowledge, or provide a more detailed exploration of some of the topics mentioned in different sections of the book. In the same way, a series of questions is presented at the end of each chapter, the reflection and discussion of which aims to help the reader to improve his/her understanding of the material covered. Among the references cited in the text, five readings are recommended to allow the student to delve, in an accessible manner, into the topics addressed in each chapter.

As far as possible, the models that were chosen for the text were programmed in *NetLogo*. The reasons for selecting this particular software are as follows: 1) many of these models, being available in the developer's library, are freely attainable and can be downloaded [0.1], while others are located on different internet pages; 2) it is a platform specifically designed to build agent-based models; 3) the software contains an easily comprehensible language and the skills required to manage it can be acquired relatively quickly; 4) it comes with a highly didactic, interactive manual; 5) the platform is available for Windows, Unix and Mac operating systems.

Contribution and acknowledgements

I am not aware of the existence of another text of this nature written in English or Spanish. Libraries have several books available with different levels of sophistication explaining the theories of complexity or networks, with the purpose of showing their relevance to the study of social or natural phenomena in general. There also exist a large number of books containing a compilation of agent-based models dedicated to the study of specific social problems.

In contrast to these materials, the structure with which this text was designed aims to take the reader by the hand, on a journey that will allow him/her to enter an alternative paradigm to the neoclassical one. The book will make it possible to get to know different methodological approaches that are very helpful for developing models and testing socio-economic theories. It should be noted that the purpose of this work is not to describe all the theoretical and empirical minutiae required for the construction of computational models. However, and throughout the text, some general ideas are described that may be useful to anyone interested in building theories of complexity in relation to economic, political and sociological phenomena.

It should be said that the set of theories, models, threads of reasoning and examples presented in this book is comprised of the contributions of countless researchers. Thus, although this is a text designed for teaching, relevant citations are included to highlight the authorship of the material referred to. The book was written in the hope that this collage does not detract from the meaning of the original models or theories but, rather, that it facilitates the construction of an analytical scaffolding within which to study socioeconomic phenomena from the perspective of complexity. It remains for you, dear reader, to decide on the value of the material here presented.

Finally, I would like to thank the colleagues who read one or several of the chapters of the different versions, which I wrote over sixteen years, for their comments, which unquestionably helped me to improve the text. My special gratitude, in alphabetical order, goes to Raymundo Campos, Fernando Castañeda, Adolfo García de la Sienra, Carlos Gershenson, Verónica González, Omar Guerrero, Gerardo Íñiguez, Felipe Lara, Fernanda Márquez, Martín Puchet, Mariano Rojas, Judith Santiago, John Scott, Juan Rafael Vargas and Daniel Ventosa. I also thank Lidija Mavra for her translation to English and meticulous editorial work. Regardless of whether the text has been revised based on these comments, I do want to stress that all points of view expressed here and any remaining errors are my responsibility.

Hyperlinks

0.1 http://ccl.northwestern.edu/netlogo/

0.2 http://www.intro-to-abm.com/

0.3 http://www.railsback-grimm-abm-book.com/

0.4 https://intro2abm.com/

0.5 https://www.comses.net/

0.6 https://payhip.com/b/VhKb/

0.7 https://www.amazon.com/Agent-Based-Spatial-Simulation-NetLogo-Volume/dp/1785480553/

0.8 https://www.youtube.com/user/gabrielwurzer/

0.9 http://www.complexityexplorer.org/

0.10 http://hamill.co.uk/lynne-hamill/abm-in-economics/