

Methodos Series

Methodological Prospects in the Social Sciences

Volume 13

Editors

Daniel Courgeau, Institut National d'Études Démographiques
Robert Franck, Université Catholique de Louvain

Editorial Advisory Board

Peter Abell, London School of Economics
Patrick Doreian, University of Pittsburgh
Sander Greenland, UCLA School of Public Health
Ray Pawson, Leeds University
Cees van der Eijk, University of Amsterdam
Bernard Walliser, Ecole Nationale des Ponts et Chaussées, Paris
Björn Wittrock, Uppsala University
Guillaume Wunsch, Université Catholique de Louvain

This Book Series is devoted to examining and solving the major methodological problems social sciences are facing. Take for example the gap between empirical and theoretical research, the explanatory power of models, the relevance of multilevel analysis, the weakness of cumulative knowledge, the role of ordinary knowledge in the research process, or the place which should be reserved to “time, change and history” when explaining social facts. These problems are well known and yet they are seldom treated in depth in scientific literature because of their general nature.

So that these problems may be examined and solutions found, the series prompts and fosters the setting up of international multidisciplinary research teams, and it is work by these teams that appears in the Book Series. The series can also host books produced by a single author which follow the same objectives. Proposals for manuscripts and plans for collective books will be carefully examined.

The epistemological scope of these methodological problems is obvious and resorting to Philosophy of Science becomes a necessity. The main objective of the Series remains however the methodological solutions that can be applied to the problems in hand. Therefore the books of the Series are closely connected to the research practices.

More information about this series at <http://www.springer.com/series/6279>

Eric Silverman

Methodological Investigations in Agent-Based Modelling

With Applications for the Social Sciences

With contribution by

Daniel Courceau • Robert Franck

Jakub Bijak • Jason Hilton

Jason Noble • John Bryden



Springer Open

Eric Silverman
MRC/CSO Social and Public Health
Sciences Unit
University of Glasgow
Glasgow, UK



Methodos Series

ISBN 978-3-319-72406-5

ISBN 978-3-319-72408-9 (eBook)

<https://doi.org/10.1007/978-3-319-72408-9>

Library of Congress Control Number: 2017962298

© The Author(s) 2018. This book is an open access publication.

Open Access This book is licensed under the terms of the Creative Commons Attribution 4.0 International License (<http://creativecommons.org/licenses/by/4.0/>), which permits use, sharing, adaptation, distribution and reproduction in any medium or format, as long as you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons license and indicate if changes were made.

The images or other third party material in this book are included in the book's Creative Commons license, unless indicated otherwise in a credit line to the material. If material is not included in the book's Creative Commons license and your intended use is not permitted by statutory regulation or exceeds the permitted use, you will need to obtain permission directly from the copyright holder.

The use of general descriptive names, registered names, trademarks, service marks, etc. in this publication does not imply, even in the absence of a specific statement, that such names are exempt from the relevant protective laws and regulations and therefore free for general use.

The publisher, the authors and the editors are safe to assume that the advice and information in this book are believed to be true and accurate at the date of publication. Neither the publisher nor the authors or the editors give a warranty, express or implied, with respect to the material contained herein or for any errors or omissions that may have been made. The publisher remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

Printed on acid-free paper

This Springer imprint is published by Springer Nature

The registered company is Springer International Publishing AG

The registered company address is: Gewerbestrasse 11, 6330 Cham, Switzerland

*For Takako:
You make it all worthwhile.*

Foreword

Following the aims of the *Methodos Series* perfectly, this 13th volume on agent-based models provides a general view of the problems raised by this approach and shows how these problems may be solved.

These methods are derived from computer simulation studies used by mathematicians and physicists. They are now applied in many social disciplines such as artificial life (Alife), political sciences, evolutionary psychology, demography, and many others. Those who introduced them often took care not to consider each social science separately but to view them as a whole, incorporating a wide spectrum of social processes – demographic, economic, sociological, political, and so on.

Rather than modelling specific data, this approach models theoretical ideas and is based on computer simulation. Its aim is to understand how the behaviour of biological, social, or more complex systems arises from the characteristics of the individuals or agents composing the said system. As Billari and Prskawetz (2003, p. 42) said,

Different to the approach of experimental economics and other fields of behavioural science that aim to understand why specific rules are applied by humans, agent-based computational models pre-suppose rules of behaviour and verify whether these micro based rules can explain macroscopic regularities.

This is, therefore, a bottom-up approach, with population-level behaviour emerging from rules of behaviour of autonomous individuals. These rules need to be clearly discussed; unfortunately, this approach is now used without sufficient discussions in many social sciences. It eliminates the need for empirical data on personal or social characteristics to explain a phenomenon, as it is based on simple decision-making rules followed by individuals, which can explain some real-world phenomena. But how can we find these rules? As Burch (2003, p. 251) puts it,

A model explains some real-world phenomenon if a) the model is appropriate to the real-world system [...] and b) if the model logically implies the phenomenon, in other words, if the phenomenon follows logically from the model as specified to fit a particular part of the real world.

Also, a theoretical model of this kind cannot be validated in the same way as an empirical model with the “covering law” approach, which hinders social research and leads to a pessimistic view of the explanatory power of the social sciences. In Franck’s words (Franck 2002, p. 289),

But, one has ceased to credit deduction with the power of explaining phenomena. Explaining phenomena means discovering principles which are implied by the phenomena. It does not mean discovering phenomena which are implied by the principles.

As the agent-based approach focuses on the mechanisms driving the actions of individuals or agents, it will simulate the evolution of such a population from simple rules of behaviour. It may thus use game theory, complex systems theory, emergence, evolutionary programming and – to introduce randomness – Monte Carlo methods. It may also use survey data, not to explain the phenomenon studied, but only to verify if the parameters used in the simulation lead to a behaviour similar to the one observed in the survey.

As we have already said, such an approach raises many problems which this volume will try to answer. We will present here these main problems, letting the reader see how Silverman has treated it.

The first problem is that these models “are intended to represent the import and impact of individual actions on the macro-level patterns observed in a complex system” (Courgeau et al. 2017, p. 38). This implies that a phenomenon emerging at the aggregate level can be entirely explained by individual behaviour. Holland (2012, p. 48), however, states that agent-based models include “little provision for agent conglomerates that provide building blocks and behaviour at a higher level of organisation.” For instance, a multilevel study on the effects of an individual characteristic (being a farmer) and the corresponding aggregate characteristic (the proportion of farmers living in an area) on the probability of internal migration in Norway shows that the effects are contradictory (Courgeau 2007): it seems hard to explain a macro-characteristic acting positively by a micro-characteristic acting negatively. In fact, micro-level rules are often hard to link to aggregate-level rules, and I believe that aggregate-level rules cannot be modelled with a purely micro approach, for they transcend the behaviours of the component agents.

The second problem is that this approach is basically bottom-up. However, it seems important to take into consideration simultaneously a top-down process from higher-level properties to lower-level entities. More specifically, we should speak of a *micro-macro link* (Conte et al. 2012, p. 336) that “is the loop process by which behaviour at the individual level generates higher-level structures (bottom-up process), which feedback to the lower level (top-down), sometimes reinforcing the producing behaviour either directly or indirectly”. The bottom-up approach of a standard agent-based model cannot take such a reciprocal micro-macro link into account, given that it only simulates one level of analysis.

The third problem concerns the validation of an agent-based model. Such an approach imitates human behaviour using some well-chosen mechanisms. It may be judged successful when it accurately reproduces the structure of this behaviour.

Determining success, however, requires a method very different from the standard tests used to verify the validity of the effects of different characteristics in the other approaches. Such tests can be performed in the natural sciences but are more difficult in the social sciences. As Küppers and Lenhard observe (Günter et al. 2005, paragraph 1.3),

The reliability of the knowledge produced by computer simulation is taken for granted if the physical model is correct. In the second case of social simulations in general there is no theoretical model on which one could rely. The knowledge produced in this case seems to be valid if some characteristic of the social dynamics known from experience with the social world are reproduced by the simulation.

To determine if such an exploration has been successful, we need to consider different aspects. First, how do we test that there are no other models offering a better explanation of the observed phenomenon? Researchers often try out different kinds of models so they can choose the one most consistent with empirical data. But this hardly solves the problem, as there is an infinity of models that can predict the same empirical result as well or even better. Second, how do we test that the chosen model has a good fit with the observed data? Unfortunately, there is no clearly defined procedure for testing the fit of a simulation model, such as significance tests for the approaches described earlier. We can conclude that there are no clear verification and validation procedures for agent-based models in the social sciences.

While the agent-based approach appears to resemble event-history analysis, for it focuses on individual behaviour, it nevertheless aims to explain collective behaviour. At that point, the key question is: how do we generate macroscopic regularity using simple individual rules? Conte et al. (2012, p. 340) perfectly describe the difficulties encountered:

First, how to find out the simple local rules? How to avoid *ad hoc* and arbitrary explanations? As already observed, one criterion has often been used, i.e., choose the conditions that are sufficient to generate a given effect. However, this leads to a great deal of alternative options, all of which are to some extent arbitrary.

Without factoring in the influence of networks on individual behaviour, we can hardly obtain a macro behaviour merely by aggregating individual behaviours. To obtain more satisfactory models, we must introduce decision-making theories. Unfortunately, the choice of theory is influenced by the researcher's discipline and can produce highly divergent results for the same phenomenon studied.

In order to go further, Chap. 9, co-authored by Jakub Bijak, Daniel Courgeau, Robert Franck and Eric Silverman, proposes for demography the enlargement of agent-based models to a model-based research. This will not be a new paradigm in the traditional sense, as with the cross-sectional, the cohort, the event-history and the multilevel approaches, but a new way to overcome the limitations of demographic knowledge. It is a research programme which adds a new avenue of empirical relevance to demographic research. The examples given in the following chapters, despite the simplicity of the models used, give us a glimpse of the importance of model-based demography.

I hope I have given to the reader of this volume a clear idea of its importance for social sciences.

Mougins, France
August 2017

Daniel Courgeau

References

- Billari, F., & Prskawetz, A. (2003). *Agent-based computational demography: Using simulation to improve our understanding of demographic behaviour*. Heidelberg: Physica Verlag.
- Burch, T. K. (2003). Data, models, theory and reality: The structure of demographic knowledge. In F. Billari & A. Prskawetz (Eds.), *Agent-based computational demography: Using simulation to improve our understanding of demographic behaviour* (pp. 19–40). Heidelberg: Physica Verlag.
- Conte, R., Gilbert, N., Bonelli, G., Cioffi-Revilla, C., Deffuant, G., Kertesz, V., Loreto, V., Moat, S., Nadal, J.-p., Sanchez, A., Nowak, A., Flache, A., San Miguel, M., & Helbing, D. (2012). Manifesto of computational social science. *European Physical Journal Special Topics*, 214, 325–346.
- Courgeau, D. (2007). *Multilevel synthesis: From the group to the individual*. Dordrecht: Springer.
- Courgeau, D., Bijak, J., Franck, R., & Silverman, E. (2017). Model-based demography: Towards a research agenda. In A. Grow & J. Van Bavel (Ed.), *Agent-based modelling and population studies* (Springer series on demographic methods and population analysis, pp. 29–51). Berlin/Heidelberg: Springer.
- Franck, R. (Ed.). (2002). *The explanatory power of models: Bridging the gap between empirical and theoretical research in the social sciences* (Methodos series 1). Boston/Dordrecht/London: Kluwer Academic.
- Holland, J. H. (2012). *Signals and boundaries*. Cambridge: MIT Press.
- Küppers, G., & Lenhard, J. (2005). Validation of simulation: Patterns in the social and natural sciences. *Journal of Artificial Societies and Social Simulation*, 8(4), 3.

Acknowledgements

This volume covers more than 10 years of research, stretching back to the start of my PhD in 2003. Over this lengthy period, this work has been supported by a number of institutions and funders. Chapters 1 through 8 are substantially based on my PhD research, completed at the School of Computing at the University of Leeds from 2003 to 2007. Chapters 9 through 11 are based on a work completed at the University of Southampton between 2010 and 2015 during the Care Life Cycle Project, funded by Engineering and Physical Sciences Research Council grant EP/H021698/1. Teesside University supported my work on the manuscript between 2015 and 2017. The completion of the manuscript was also supported by the Complexity in Health Improvement programme at the MRC/CSO Social and Public Health Sciences Unit at the University of Glasgow, with QQR funding code MC_UU_12017/14.

Of course this work has also benefitted from the collaboration, vital input and feedback from a host of colleagues and friends. At Leeds, my thanks go out to Jason Noble for being such a good friend, close colleague and trusted confidant throughout my years in research; Seth Bullock for his supervision and collaboration during my PhD; David Hogg for taking on supervision duties and supporting me during a critical period in my PhD; John Bryden for being a close collaborator and dear friend and for introducing me to Babylon 5; and Roger Boyle and Peter Jimack for being so supportive throughout my PhD studies.

At Southampton, thanks once again go to Jason and Seth, for supporting me throughout my postdoc experience and for fostering a great community within the research group. Special mention must go to Jakub Bijak, close collaborator on key chapters of this volume, trusted friend and a spectacularly talented researcher. Without his support and encouragement, this volume would never have come into being. Part III of this volume came to life thanks to exciting collaborations with Daniel Courgeau, Robert Franck and Jakub, and I feel very privileged to have been part of those conversations. I was also fortunate to be able to discuss the future of model-based demography with Thomas Burch, whose work I hold in very high esteem.

At Teesside, I was lucky to share offices with Ian Wood, who was a great source of support and a great colleague, without whom my time there would have been much poorer. Thanks also to Mark Cavazza for his support during his time there and his dedication to the union. Thanks as well to colleagues Julie Porteous, Fred Charles and The Anh Han – I am glad we will continue working together in the coming years.

For all their encouragement and kindness, I am indebted to my parents, Lewis and Linda Silverman, who have never failed to be a continuous source of inspiration throughout my academic career. Takashi Ikegami has been an inspiration to me since we first met in Boston in 2004; his enthusiasm and belief in Alife and his willingness to break boundaries in research have been a pleasure to experience. A heartfelt thanks also go to my friend and former housemate David Mitchell, who defined my years in Leeds and made my time there a true joy.

Last but certainly not least, thank you to my wife, Takako, who has showed such endless patience with my strange working hours, bizarre sleeping schedule and rambling monologues on obscure topics. Thank you for sticking with me, even when my brain was wandering off somewhere else entirely.

Contents

Part I Agent-Based Models

1	Introduction	3
1.1	Overview	3
1.2	Artificial Life as Digital Biology	4
1.2.1	Artificial Life as Empirical Data-Point	4
1.3	Social Simulation and Sociological Relevance	5
1.3.1	Methodological Concerns in Social Simulation	5
1.4	Case Study: Schelling’s Residential Segregation Model	6
1.4.1	Implications of Schelling’s Model	6
1.5	Social Simulation in Application: The Case of Demography	7
1.5.1	Building Model-Based Demography	7
1.6	General Summary	7
1.6.1	Alife Modelling	8
1.6.2	Simulation for the Social Sciences	8
1.6.3	Schelling’s Model as a Case Study in Modelling	8
1.6.4	Developing a Model-Based Demography	9
1.6.5	General Conclusions of the Text: Messages for the Modeller	9
1.6.6	Chapter Summaries	10
1.6.7	Contributions	13
	References	14
2	Simulation and Artificial Life	17
2.1	Overview	17
2.2	Introduction to Simulation Methodology	18
2.2.1	The Goals of Scientific Modelling	18
2.2.2	Mathematical Models	18
2.2.3	Computational Models	19
2.2.4	The Science Versus Engineering Distinction	20

- 2.2.5 Connectionism: Scientific Modelling in Psychology 21
- 2.2.6 Bottom-Up Modelling and Emergence 22
- 2.3 Evolutionary Simulation Models and Artificial Life 22
 - 2.3.1 Genetic Algorithms and Genetic Programming 22
 - 2.3.2 Evolutionary Simulations and Artificial Life 23
 - 2.3.3 Bedau and the Challenges Facing ALife 24
- 2.4 Truth in Simulation: The Validation Problem 26
 - 2.4.1 Validation and Verification in Simulation 26
 - 2.4.2 The Validation Process in Engineering Simulations 26
 - 2.4.3 Validation in Scientific Simulations: Concepts of Truth .. 27
 - 2.4.4 Validation in Scientific Models: Koppers and
Lenhard Case Study 28
- 2.5 The Connection Between Theory and Simulation 29
 - 2.5.1 Simulation as ‘Miniature Theories’ 29
 - 2.5.2 Simulations as Theory and Popperian Falsificationism ... 29
 - 2.5.3 The Quinean View of Science 30
 - 2.5.4 Simulation and the Quinean View 31
- 2.6 ALife and Scientific Explanation 32
 - 2.6.1 Explanation Through Emergence 32
 - 2.6.2 Strong vs Weak Emergence 33
 - 2.6.3 Simulation as Thought Experiment 34
 - 2.6.4 Explanation Compared: Simulations vs
Mathematical Models 35
- 2.7 Summary and Conclusions 36
- References 36
- 3 Making the Artificial Real 39**
 - 3.1 Overview 39
 - 3.2 Strong vs. Weak ALife and AI 40
 - 3.2.1 Strong vs. Weak AI: Creating Intelligence 40
 - 3.2.2 Strong vs. Weak ALife: Creating Life? 40
 - 3.2.3 Defining Life and Mind 40
 - 3.3 Levels of Artificiality 41
 - 3.3.1 The Need for Definitions of Artificiality 41
 - 3.3.2 Artificial¹: Examples and Analysis 42
 - 3.3.3 Artificial²: Examples and Analysis 42
 - 3.3.4 Keeley’s Relationships Between Entities 43
 - 3.4 ‘Real’ AI: Embodiment and Real-World Functionality 43
 - 3.4.1 Rodney Brooks and ‘Intelligence Without Reason’ 43
 - 3.4.2 Real-World Functionality in Vision and Cognitive
Research 44
 - 3.4.3 The Differing Goals of AI and ALife: Real-World
Constraints 44

3.5	‘Real’ Alife: Langton and the Information Ecology	45
3.5.1	Early Alife Work and Justifications for Research	45
3.5.2	Ray and Langton: Creating Digital Life?	45
3.5.3	Langton’s Information Ecology	46
3.6	Toward a Framework for Empirical Alife	47
3.6.1	A Framework for Empirical Science in AI	47
3.6.2	Newell and Simon Lead the Way	48
3.6.3	Theory-Dependence in Empirical Science	49
3.6.4	Artificial Data in Empirical Science	50
3.6.5	Artificial Data and the ‘Backstory’	53
3.6.6	Silverman and Bullock’s Framework: A PSS Hypothesis for Life	54
3.6.7	The Importance of Backstory for the Modeller	55
3.6.8	Where to Go from Here	56
3.7	Summary and Conclusions	57
	References	58
4	Modelling in Population Biology	61
4.1	Overview	61
4.2	Levins’ Framework: Precision, Generality, and Realism	62
4.2.1	Description of Levins’ Three Dimensions	62
4.3	Levins’ L1, L2 and L3 Models: Examples and Analysis	63
4.3.1	L1 Models: Sacrificing Generality	63
4.3.2	L2 Models: Sacrificing Realism	64
4.3.3	L3 Models: Sacrificing Precision	64
4.4	Orzack and Sober’s Rebuttal	64
4.4.1	The Fallacy of Clearly Delineated Model Dimensions ...	64
4.4.2	Special Cases: The Inseparability of Levins’ Three Factors	65
4.5	Resolving the Debate: Intractability as the Fourth Factor	66
4.5.1	Missing the Point? Levins’ Framework as Pragmatic Guideline	66
4.5.2	Odenbaugh’s Defence of Levins	66
4.5.3	Intractability as the Fourth Factor: A Refinement	67
4.6	A Levinsian Framework for Alife	69
4.6.1	Population Biology vs. Alife: A Lack of Data	69
4.6.2	Levinsian Alife: A Framework for Artificial Data?	70
4.6.3	Resembling Reality and Sites of Sociality	70
4.6.4	Theory-Dependence Revisited	72
4.7	Tractability Revisited	72
4.7.1	Tractability and Braitenberg’s Law	72
4.7.2	David Marr’s Classical Cascade	74
4.7.3	Recovering Algorithmic Understanding	75
4.7.4	Randall Beer and Recovering Algorithmic Understanding	75
4.7.5	The Lure of Artificial Worlds	76

- 4.8 Saving Simulation: Finding a Place for Artificial Worlds 77
 - 4.8.1 Shifting the Tractability Ceiling 77
 - 4.8.2 Simulation as Hypothesis-Testing 78
- 4.9 Summary and Conclusion..... 79
- References..... 80

Part II Modelling Social Systems

- 5 Modelling for the Social Sciences 85**
 - Eric Silverman and John Bryden
 - 5.1 Overview..... 85
 - 5.2 Agent-Based Models in Political Science 86
 - 5.2.1 Simulation in Social Science: The Role of Models 86
 - 5.2.2 Axelrod’s Complexity of Cooperation..... 87
 - 5.3 Lars-Erik Cederman and Political Actors as Agents 87
 - 5.3.1 Emergent Actors in World Politics a Modelling Manifesto 87
 - 5.3.2 Criticism from the Political Science Community 88
 - 5.3.3 Areas of Contention: The Lack of ‘Real’ Data..... 89
 - 5.4 Cederman’s Model Types: Examples and Analysis 89
 - 5.4.1 Type 1: Behavioural Aspects of Social Systems 89
 - 5.4.2 Type 2: Emerging Configurations..... 90
 - 5.4.3 Type 3: Interaction Networks 91
 - 5.4.4 Overlap in Cederman’s Categories..... 91
 - 5.5 Methodological Peculiarities of the Political Sciences 92
 - 5.5.1 A Lack of Data: Relating Results to the Real World..... 92
 - 5.5.2 A Lack of Hierarchy: Interdependence of Levels of Analysis 93
 - 5.5.3 A Lack of Clarity: Problematic Theories 93
 - 5.6 In Search of a Fundamental Theory of Society 93
 - 5.6.1 The Need for a Fundamental Theory 93
 - 5.6.2 Modelling the Fundamentals 94
 - 5.7 Systems Sociology: A New Approach for Social Simulation?..... 95
 - 5.7.1 Niklas Luhmann and Social Systems 95
 - 5.7.2 Systems Sociology vs. Social Simulation 96
 - 5.8 Promises and Pitfalls of the Systems Sociology Approach 97
 - 5.8.1 Digital Societies? 97
 - 5.8.2 Rejecting the PSS Hypothesis for Society..... 98
 - 5.9 Social Explanation and Social Simulation 98
 - 5.9.1 Sawyer’s Analysis of Social Explanation 99
 - 5.9.2 Non-reductive Individualism 99
 - 5.9.3 Macy and Miller’s View of Explanation..... 101
 - 5.9.4 Alife and Strong Emergence 102
 - 5.9.5 Synthesis 102
 - 5.10 Summary and Conclusion..... 103
 - References..... 104

6	Analysis: Frameworks and Theories for Social Simulation	107
6.1	Overview	107
6.2	Frameworks and ALife: Strong ALife	108
6.2.1	Strong ALife and the Lack of ‘Real’ Data	108
6.2.2	Artificial ¹ vs Artificial ² : Avoiding the Distinction	108
6.2.3	Information Ecologies: The Importance of Back-stories	108
6.3	Frameworks and ALife: Weak ALife	109
6.3.1	Artificial ¹ vs. Artificial ² : Embracing the Distinction	109
6.3.2	Integration of Real Data: Case Studies	110
6.3.3	Backstory: Allowing the Artificial	110
6.4	The Legacy of Levins	111
6.4.1	The 3 Types: A Useful Hierarchy?	111
6.4.2	Constraints of the Fourth Factor	112
6.5	Frameworks and Social Science	112
6.5.1	Artificial ¹ vs. Artificial ² : A Useful Distinction?	112
6.5.2	Levins: Still Useful for Social Scientists?	113
6.5.3	Cederman’s 3 Types: Restating the Problem	115
6.5.4	Building the Framework: Unifying Principles for Biology and Social Science Models	116
6.5.5	Integration of Real Data	117
6.6	Views from Within Social Simulation	118
6.6.1	Finding a Direction for Social Simulation	118
6.6.2	Doran’s Perspective on the Methodology of Artificial Societies	119
6.6.3	Axelrod and Tesfatsion’s Perspective: The Beginner’s Guide to Social Simulation	120
6.7	Summary and Conclusions	121
	References	122
7	Schelling’s Model: A Success for Simplicity	125
7.1	Overview	125
7.2	The Problem of Residential Segregation	126
7.2.1	Residential Segregation as a Social Phenomenon	126
7.2.2	Theories Regarding Residential Segregation	126
7.3	The Checkerboard Model: Individual Motives in Segregation	127
7.3.1	The Rules and Justifications of the Model	127
7.3.2	Results of the Model: Looking to the Individual	127
7.3.3	Problems of the Model: A Lack of Social Structure	128
7.4	Emergence by Any Other Name: Micromotives and Macrobehaviour	128
7.4.1	Schelling’s Justifications: A Valid View of Social Behaviour?	128
7.4.2	Limiting the Domain: The Acceptance of Schelling’s Result	129

- 7.4.3 Taylor’s Sites of Sociality: One View of the Acceptance of Models 130
- 7.4.4 The Significance of Taylor: Communicability and Impact 130
- 7.5 Fitting Schelling to the Modelling Frameworks 131
 - 7.5.1 Schelling and Silverman-Bullock: Backstory 131
 - 7.5.2 Schelling and Levins-Silverman: Tractability 131
 - 7.5.3 Schelling and Cederman: Avoiding Complexity 132
- 7.6 Lessons from Schelling 132
 - 7.6.1 Frameworks: Varying in Usefulness 132
 - 7.6.2 Tractability: A Useful Constraint 133
 - 7.6.3 Backstory: Providing a Basis 133
 - 7.6.4 Artificiality: When it Matters 134
 - 7.6.5 The Practical Advantages of Simplicity 135
- 7.7 Schelling vs Doran and Axelrod 136
 - 7.7.1 Doran’s View: Supportive of Schelling?..... 136
 - 7.7.2 Schelling vs Axelrod: Heuristic Modelling 137
- 7.8 Schelling and Social Simulation: General Criticisms 137
 - 7.8.1 Lack of ‘Real’ Data..... 137
 - 7.8.2 Difficulties of Social Theory 138
 - 7.8.3 Schelling and the Luhmannian Perspective 138
 - 7.8.4 Ramifications for Social Simulation and Theory..... 139
- 7.9 The Final Hurdle: Social Explanation 140
 - 7.9.1 Schelling’s Model and the Explanation Problem..... 140
 - 7.9.2 Implications for Luhmannian Social Explanation..... 141
- 7.10 Summary and Conclusions 142
- References..... 143
- 8 Conclusions..... 145**
 - 8.1 Overview..... 145
 - 8.2 Lessons from Alife: Backstory and Empiricism 145
 - 8.2.1 Backstory in Alife 145
 - 8.2.2 Schelling’s Avoidance of the Issue 146
 - 8.3 The Lure of Artificial Worlds 147
 - 8.3.1 Levinsian Modelling..... 147
 - 8.3.2 Levins and Artificial Worlds 147
 - 8.4 Modelling in Alife: Thoughts and Conclusions..... 148
 - 8.4.1 Lessons from Schelling..... 148
 - 8.4.2 The Power of Simplicity 149
 - 8.4.3 The Scope of Models 149
 - 8.5 The Difficulties of Social Simulation 150
 - 8.5.1 Social Simulation and the Backstory 150
 - 8.5.2 Social Simulation and Theory-Dependence 150
 - 8.5.3 Social Simulation and Explanation 151

- 8.6 Schelling’s Approach 151
 - 8.6.1 Schelling’s Methodological and Theoretical Stance 151
 - 8.6.2 Difficulties in Social Explanation 152
 - 8.6.3 Schelling and Theory-Dependence 153
- 8.7 Luhmannian Modelling 153
 - 8.7.1 Luhmann and Theory-Dependence 153
 - 8.7.2 Luhmann and New Social Theory 154
 - 8.7.3 Luhmann and Artificial Worlds 154
- 8.8 Future Directions for Social Simulation..... 155
 - 8.8.1 Luhmannian Modelling as a Way Forward 155
 - 8.8.2 What Luhmann is Missing: Non-reductive Individualism 155
 - 8.8.3 Integrating Lessons from ALife Modelling 156
 - 8.8.4 Using the Power of Simplicity 157
- 8.9 Conclusions and Future Directions 157
 - 8.9.1 Forming a Framework 157
 - 8.9.2 Messages for the Modeller 159
 - 8.9.3 The Tension Between Theory-Dependence and Theoretical Backstory 160
 - 8.9.4 Putting Agent-Based Modelling for the Social Sciences into Practice 161
- References..... 162

Part III Case Study: Simulation in Demography

- 9 Modelling in Demography: From Statistics to Simulations..... 167**
 Jakub Bijak, Daniel Courgeau, Robert Franck, and Eric Silverman
 - 9.1 An Introduction to Demography 167
 - 9.2 The Historical Development of Demography 168
 - 9.2.1 Early Statistical Tools in Demography 169
 - 9.2.2 Cohort Analysis..... 170
 - 9.2.3 Event-History Analysis..... 170
 - 9.2.4 Multilevel Approaches 171
 - 9.2.5 Cumulativity 171
 - 9.3 Uncertainty, Complexity and Interactions in Population Systems 173
 - 9.3.1 Uncertainty in Demographic Forecasts 173
 - 9.3.2 The Problem of Aggregation 173
 - 9.3.3 Complexity vs. Simplicity..... 174
 - 9.3.4 Addressing the Challenges 174
 - 9.4 Moving Toward a Model-Based Demography 175
 - 9.4.1 The Explanatory Capacity of Simulation 176
 - 9.4.2 The Difficulties of Demographic Simulation 177
 - 9.5 Demography and the Classical Scientific Programme 177
 - 9.6 Stages of Model-Based Demographic Research 179

- 9.7 Overcoming the Limitations of Demographic Knowledge 180
- 9.8 The Pragmatic Benefits of Model-Based Demography 181
- 9.9 Benefits of the Classical Scientific Approach 182
- 9.10 Conclusions 183
- References 185
- 10 Model-Based Demography in Practice: I 189**
Eric Silverman, Jakub Bijak, and Jason Hilton
- 10.1 Introduction 189
- 10.2 Demographic Modelling Case Studies 189
 - 10.2.1 The Decline of the Anasazi 190
 - 10.2.2 The Wedding Ring 191
- 10.3 Extending the Wedding Ring 193
 - 10.3.1 Model Motivations 193
 - 10.3.2 Simulated Individuals 194
- 10.4 Extension Details 196
 - 10.4.1 Spatial and Demographic Extensions 196
 - 10.4.2 Health Status Component 197
 - 10.4.3 Agent Behaviours and Characteristics 197
 - 10.4.4 Simulation Properties 198
- 10.5 Simulation Results 199
 - 10.5.1 Population Change 199
 - 10.5.2 Simple Sensitivity Analysis 199
 - 10.5.3 Scenario Generation Example 201
 - 10.5.4 Spatial Distribution of Informal Care 203
 - 10.5.5 Sensitivity Analysis Using Emulators 204
- 10.6 The Wedding Doughnut: Discussion and Future Directions 206
- 10.7 General Conclusions 207
- References 209
- 11 Model-Based Demography in Practice: II 211**
Eric Silverman, Jason Noble, Jason Hilton, and Jakub Bijak
- 11.1 Introduction 211
- 11.2 Model Motivations 211
- 11.3 The ‘Linked Lives’ Model 212
 - 11.3.1 Basic Model Characteristics 212
 - 11.3.2 Health Status Component 213
 - 11.3.3 Agent Behaviours and Demographic Elements 215
- 11.4 Results 216
 - 11.4.1 Parameter Sweeps 216
 - 11.4.2 Sensitivity Analysis with Emulators 219
- 11.5 The Power of Scenario-Based Approaches 221
- References 222
- 12 Conclusions 225**
- 12.1 Model-Based Demography: The Story so Far 225
- 12.2 The Practice of Model-Based Demography 226

- 12.3 Limitations of the Model-Based Approach 227
 - 12.3.1 Demographic Social Simulation 227
 - 12.3.2 Demographic Systems Sociology 228
- 12.4 The Future of Model-Based Demography 229
- 12.5 Model-Based Demography as an Exemplar for Social Science Modelling 230
 - 12.5.1 The Advantages of Developing a Framework 231
 - 12.5.2 Model-Based Social Sciences 232
- 12.6 A Manifesto for Social Science Modelling? 233
- References 234

Acronyms

In general I have attempted to keep this volume free of excessive abbreviations, but the acronyms below will appear at times given their widespread usage in related fields of research.

- ABCD Agent-Based Computational Demography. This term describes an approach to the discipline of demography which incorporates agent-based modelling.
- ABM Agent-Based Model. These are computer simulations designed to examine the behaviour and interactions of autonomous agents.
- ABSS Agent-Based Social Simulation. An approach to social simulation which explicitly focuses on the use of agent-based models.