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Volume 13

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Eric Silverman

Methodological Investigations in Agent-Based Modelling

With Applications for the Social Sciences

With contribution by
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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

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Contents

Part I Agent-Based Models

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.