Chapter 4
Agent-Based Simulation Modeling:
Definitions and a Methodological Proposal

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ABSTRACT

Computer simulations are a powerful tool for scientific research, but lack an accepted methodology for their use, and consequently their results are generally received with skepticisms. This chapter proposes a methodological approach allowing to formally unify the treatment of "traditional" quantitative phenomena with that of phenomena from economics or biology that prevent a universal adoption of data-centered methods. We propose to adopt the explanation as the basic unit of knowledge, which is able to cover all possible cases. From this assumption, we can derive the conclusion that simulation models fail to deliver their full potential as scientific investigative tool because their implementations lack crucial details on the intermediate steps producing simulation results.

1 INTRODUCTION

The use of computational techniques to aid research, both for theoretical as well as for empirical purposes, is now widely established, and their methodological guidelines, albeit controversial in same cases, have been clearly defined. For example, computer assisted proofs in mathematics are an established methodology, at least since the 1997 proof of the Four-Color Theorem. Empirically oriented studies concerning complex problems have fully embraced computational techniques to crack problems in many disparate fields. Engineers regularly simulate fluid turbulence or kinetic properties of materials; biologists turns to computers to predict and interpret protein folding; meteorologists rely almost exclusively on simulations; the vast majority of trades on stock-exchanges are now ordered by algorithms; etc. Indeed, the list may continue, proving that some form of computer assistance is provided to practically any advanced human activity.

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Each of the above examples may be correctly classified as "computer simulations" in that computers are used to create a virtual representation of a given system. They also have another common feature: a clearly defined criterion to assess the adequacy of the representation for the goal pursued by its use. For example, the conjectured proof of a theorem may be shown wrong by a counter-example. A weather forecast model may be assessed against the record of actual weather. Experimental evidence can be compared to results from biological and physical experiments, etc. In essence, the detailed understanding of how the computer program performing its task may (and generally does) provide useful information, particularly to catch bugs in the code or improve subsequence versions. But, strictly speaking, this knowledge is not necessary for the final user of the results, which can be evaluated independently from the way have been originated. In short, these class of simulation programs can be black-boxed and used by people ignoring totally the internal details of their implementation. These results may well come from computer program, analytical results, or experts guesses: in all cases they admit an evaluation independent from their origin.

Besides this class of simulations there is also another type of computer simulations, which also has been in use for decades, but that met far less success than its peers mentioned above: computer simulations for research in social sciences, such as economics or sociology. This chapter sustains that the fundamental reason for the comparative failure of computer simulations as means of investigation in social science is the inadequacy of the "black-box" approach to simulations meant for research purposes. The reliability of scientific statements in these disciplines relies not on an external evaluation of final results, which, for research-oriented models, have only the comparatively minor role of certifying the adequacy of the model to represent a given system. On the contrary, it is the way the simulated results are generated that may have scientific relevance in exposing how un-observable real-world generative mechanisms actually work. Hence, black-boxing simulation programs prevents the very possibility of using simulations for at least one type of research.

In the remaining of this chapter we propose a formal definition of scientific knowledge based not on the capacity to describe reality, but on the explanatory power provided by scientific knowledge. Based on this definition we discuss the limits of assessing scientific claims in general, and then we focus on the assessment of results produced with simulation models.

2 DESCRIBING VS. EXPLAINING

When asking modelers how they believe their models should be assessed, the standard answer is related to the degree if adherence of the model results to observation of reality: the closer the model to observation, and the larger the number of real-world features captured by the model, the better fares the model against competing alternatives. In short, a model should be assessed in terms of *validation* as performed in physical sciences. Simulation models present specific difficulties, but a growing literature is starting to define how validation should be performed for this kind of models (Windrum, Fagiolo & Moneta 2007), and authors are increasingly devoting efforts in supporting the reliability of their results (Dosi, Fagiolo & Roventini 2010, Valente 2012).

However, in many cases using adherence to reality is not the best way to evaluate a model, for a number of reasons. The first paragraph below addresses this issue, indicating under which conditions accuracy in the description of reality is a good criterion and when, instead, it is a useless, or even misleading, assessment strategy for models.