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# Framing options for characterising and parameterising human agents in empirical ABM

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ABSTRACT

This paper provides empirical agent-based modellers with a generic framework that allows for a structured and unambiguous description of the characterisation and parameterisation process. As methodological recommendations depend on contextual circumstances cases are defined to distinguish particular modelling situations, which require different methods for robust model characterisation and parameterisation. Both combined allows in a comparative perspective for analysing how effectively different (sequences of) methods perform in similar contexts.



We applied the framework to eleven empirical agent-based models and results suggest that it is sufficiently generic and effective in generating transparency. This framework application also revealed some interesting methodological insights, such as a surprising lack of sophisticated statistical methods to derive explicit agent types and the under-utilisation of experimental techniques.

Ultimately, we hope that this comparative work will contribute to an improved methodological robustness of agent-based modelling in empirical situations. We also hope that the framework in combination with the distinguished modelling situations and their particular sequence of recommended methods will guide modellers and in particular newcomers by narrowing down the methodological choice and by allowing for the replication of effective parameterisation processes.

## 1. The challenge of characterising and parameterising empirical agent-based models

Agent-based modelling is losing its niche character and gaining wider recognition as a valuable methodology in empirical policy related situations (Bousquet and Le Page, 2004; Janssen and Ostrom, 2006; Smajgl et al., 2015b). This growing recognition roots in the increasing demand for methods that allow integrating indicators from various disciplines across a broader systems perspective. Agent-based modelling gains its integrative strength from a combination of factors (Gilbert, 2008; Smajgl and Bohensky, 2013; Troitzsch, 2013), in particular its ability

- to model explicitly cognitive processes, human decision making processes and social interactions,
- to model interactions between humans and technologies, the ecology, and physical dynamics,
- to spatially reference such cross-disciplinary interactions,
- to combine heterogeneous sources of knowledge, and
- to link variables at variable resolutions across various scales.

The increasing availability of micro-level data for humans, their behaviour and societal processes combined with the ongoing improvement of software (and computational processing power) to develop and run agent-based models have accelerated the empirical applications of this bottom-up modelling methodology. However, with this technology comes the potential for research to be deceivingly realistic, in particular when realism is a goal of the computational visualisation. Wrong model assumptions can easily be glossed over when presented in seemingly realistic visualisations. With the potential for integration and enhanced computational visualisation comes an amplified responsibility for robust model development and cautious model use. This introduces a set of challenges to empirical agent-based modelling, of which the

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approach for translating real-world data into robust model assumptions on the behaviour of human agents is a critical one. We refer to this process as the characterisation and parameterisation of empirical agent-based models.

In order to meet this challenge it seems promising to develop a generic framework for the characterisation and parameterisation and to identify generic types of techniques empirical modellers could implement. Based on these steps experiences could be shared across contextual differences and empirical agent-based modelling could be advanced.

Building on an earlier framework (Smajgl et al., 2011a) we present in this paper a revised characterisation and parameterisation framework and develop a decision tree to provide guidance for choosing particular methods to conduct the characterisation and parameterisation in diverse empirical situations. We aim to provide guidance for newcomers to empirical agent-based modelling in three steps. First, the framework shown in Fig. 1 visualises principle steps for the parameterisation and characterisation of empirical agent-based models. Second, sixteen modelling situations are distinguished, which can be grouped in three clusters. The modelling situations largely depend on data availability and the newcomer to empirical agent-base modelling can identify which situation comes closest to the situation he/she is facing. The third guiding step is the provision of replicable examples for the most common cases. This paper documents also results from testing the framework based on a diverse group of twelve empirical agent-based models.

## 2. Definitions

Characterization, as well as parameterization, comes prior to implementation of the model, for it is a part of the model design process itself. Characterisation aims at surfacing the intended model as an artefact: qualifying its contours and interfaces. Parameterisation aims at specifying the relation between the model and its target system: how suitable sources of information are incorporated. Characterization is currently embedded in formal description processes such as ODD (Grimm et al., 2006), which gathers at the same time description of the outcome and the modelling process.

Characterization includes first an informal step (Triebig and Klugl, 2009): given the existing knowledge from theory and prior empirical experiences of the issue, what does the model intend to capture? This leads to model formulation. This characterization is progressively funnelled in the specification of a model structure: input and output spaces as well as their interfaces with the model content. This step of characterization involves explaining what should be the entities and dynamics included in the model in order to capture main features of the target system related to the issue at stake. Characterization ends with defining a model as a transformation of a situation (an element of input space) into an element of output space, given a specific set of parameters.

Parameterisation aims at connecting model and target system, through giving values to the set of parameters in order to enable simulation. This means gathering knowledge from the target system to define these values, which we consider exogenous to the simulation dynamics and invariant along the simulation. The definition of these parameters not only precises the relation between input and output of the model (agent attributes and behaviours). It also provides information on the structure of the population of the target system so that upscaling can be performed to generate a suitable artificial population. Parameterisation is not only a matter of giving quantitative values or qualitative categorical descriptors to parameters, but to enable running the model with a set of values. Sets of categories are particularly useful for qualitative or fuzzy approaches. After an artificial population has been generated, simulations can be performed and results can provide insights for improving the characterisation and parameterisation. A first assessment of the model at this level entails characterising relations between output indicators and input situations for sets of parameters in order to check if intended features from the target system are captured.

Characterization and parameterization come prior to calibration, which is a distinct step focusing on fine-tuning of parameter

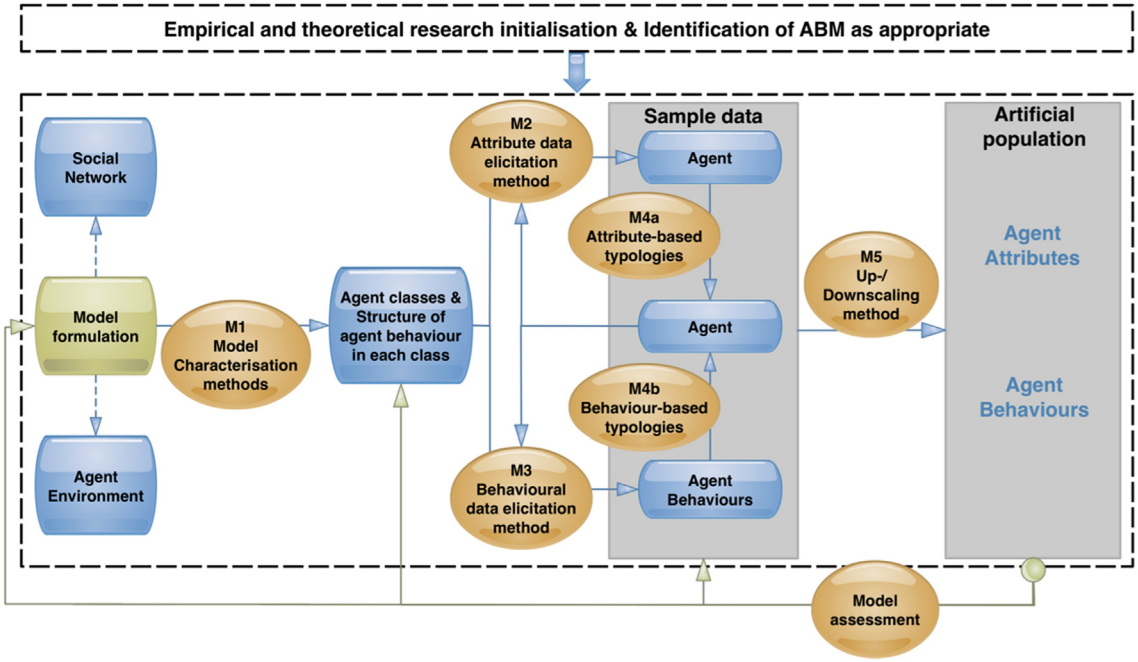


**Fig. 1.** CAP framework.