



Empirical Validation in Agent-Based Models

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ABMs and Empirical Validation

- **ABMs 20 years later...**
 - Despite a great success...
 - ... any impact on economic science?
 - Did ABMs find a place in the standard economics toolbox?
 - Published ABM papers in top economics journals
 - Figures are maybe too pessimistic but overall impact not that big...
- **Many obvious reasons why it was so...**
 - New vs. established scientific paradigm (Kuhn, Lyotard)
 - ABMs are hardly perceived as a robust, alternative paradigm
 - Why? Keywords: Heterogeneity and poor comparability
 - Assumptions and modeling design
 - Analysis of the properties of an ABM
 - **Empirical validation**

... an important remark ...

- Too much heterogeneity could be bad...
 - Difficult to compare alternative models of same phenomenon
 - Difficult to advance a new paradigm and contrast it with already existing ones
 - Having a (few) commonly accepted protocol(s) for empirical validation (and model building) would be in general better for the profession
- ... but many people think that
 - Also established paradigms are to some extent heterogeneous
 - Heterogeneity and flexibility of assumptions might be considered as *the values added of ABMs*
 - Heterogeneity is a prerequisite for the emergence of a “paradigm” (social process, scientific debate, etc.)

Fagiolo, Moneta, Windrum (2007)

- Heterogeneity in ABM Empirical Validation Exercises
 - Is it really so?
 - Taxonomizing empirical validation approaches in ABM
- Is it a problem confined only to ABMs in economics?
 - What about neoclassical economics?
 - What happens in other fields (e.g. simulations in engineering)?
- Which are the features of ABMs that favor heterogeneity in empirical validation approaches?
 - Features specific to the development of ABMs in economics
 - More general methodological problems still under debate

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Ex 1: Qualitative Simulation Modeling

- **No empirical validation**
 - Model as a laboratory to gain knowledge on the underlying causal relationships **only**, not taken to the data
- **Stylized Qualitative Models (Evolutionary-Games)**
 - Weak relation between micro-macro variables/parameters in the model and empirically observed counterparts
 - Interest in explaining the emergence of qualitative aggregate pattern (cooperation, coordination, etc.)
- **Early Evolutionary- and Industry-Dynamics Models**
 - Much more micro-founded and empirically-driven, but...
 - If any, empirical validation is done in very weak ways
- **A pessimistic view about empirical validation?**
 - Socio-economics: open-endedness, interdependence, structural change
 - Precise quantitative implications are difficult to obtain

Ex 2: Replication of Stylized-Facts

- Indirect Calibration

- Detailed data able to restrict the set of initial conditions and micro/macro parameters is difficult to gather (Kaldor)
- Empirical validation is done at the aggregate (macroeconomic) level
- Parameters and initial conditions are not restricted a priori
- Validation requires joint reproduction of a set of “stylized facts” (SFs)

- Four-Step Procedure (Fagiolo et al., 2004)

- **Step 1:** Identifying set of SFs of interest to be explained/reproduced
- **Step 2:** Keep microeconomics as close as possible to “real-world”
- **Step 3:** Find parameters and initial conditions for which the model is statistically able jointly to replicate the set of SFs
- **Step 4:** Investigation of subspace of parameters and initial conditions which “resist” to Step 3 in order to seek for causal relationships (explanations)

Ex 3: Empirical Calibration of ABMs

- **Werker and Brenner (2005)**
 - Dealing with space of initial conditions and micro/macro parameters
 - Difficult to employ theoretical arguments to restrict the set
 - Use empirical knowledge first to calibrate initial conditions and micro/macro parameters and then to validate

- **Three-Step Procedure**
 - **Step 1:** Employ empirical knowledge to calibrate initial conditions and parameters ranges
 - **Step 2:** Further restricting initial conditions and parameters space by empirically validate simulated output with real-world data
 - **Step 3:** Abduction. Seek explanations of the phenomena under study by exploring properties of the “possible worlds” that resist to previous steps

Ex 4: History-Friendly Industry Models

- **Malerba, Nelson, Orsenigo, and co-authors**
 - Models built upon detailed empirical, anecdotic, historical knowledge of phenomenon under study and employed to replicate its precise (qualitative) history

- **Prominent role for empirical data**
 - Detailed empirical (historical) data on the phenomenon under study assisting model building and validation
 - Specify agents' representation
 - Identify parameters and initial conditions
 - Empirically validate the model by comparing “simulated trace histories” with “actual history” of an industry

Where do they differ?

- Domain of application
 - Micro (industries, markets)
 - Macro (countries, world economy)
- Which kind of empirical observations does one employ?
 - Empirical data about micro/macro variables
 - Casual, historical and anecdotic knowledge
- How to employ empirical observations?
 - Assisting in model building (agents, behaviors, interactions,...)
 - Calibrating initial conditions and parameters
 - Validating simulated output
- What to do first?
 - First calibrate, then validate
 - First validate, then calibrate
 - Validate only

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Empirical Validation in Neo-Classical Models

- A lot of different, competing approaches do exist...
 - Haavelmo-Cowles (1944) Approach
 - Structural Modeling Approach (Hansen and Sargent, 1980)
 - VAR Approach (Sims, 1980)
 - Calibration Approach (Kydland and Prescott, 1982)
 - LSE Approach (Hendry, 1988)

- Some remarks on validation approaches in NCM ...
 - Validation is not employed to assess empirical validity of “core” theoretical assumptions (as often happens also in ABMs)
 - Heterogeneity of approaches partly reflects the open debate on validation in “philosophy of economics” (J.S. Mill; Friedman; Hutchinson, Blaug; McKloskey, Mirowski; Lawson, Mäki; etc.)

Empirical Validation in Simulation Models (1/2)

- **Simulated Models in Engineering**
 - Kwasnicki (1998): Debate on
 - Judging the model according to
 - Usefulness, Fecundity, Consistency, Simplicity
 - Or according to its
 - **Correctness** (validation of the model)

- **Many dimensions in model validation: Which priority?**
 - Correctness
 - A high degree of homomorphism between “layers”
 - Many layers at which this homomorphism could apply
 - Theory, Model, Model’s Variables, Real-World Variables
 - (if the model is simulated) Computer Program

Empirical Validation in Simulation Models (2/2)

Validity Concepts		Layers	Validity Concepts
	Program Validity (model vs. program)	Computer Program (Actual implementation of the model in a programming language)	
		Model	Model Validity (model vs. theory)
Theory Validity (theory vs. real-world)		Theory	
	Empirical Validity (model variables vs. empirical variables)	Model Variables (used in the model to proxy theoretical concepts)	Operational Validity (theory vs. model variables)
		Real World Variables (Empirically Observable Variables)	

... A first assessment ...

- Empirical validation of ABMs in economics
 - Many alternative methodological approaches
 - They differ as to several crucial dimensions (scope, data)

- Is it a problem confined only to ABMs in economics?
 - A lot of competing approaches characterize also
 - Mainstream economics
 - Other fields employing simulations as tool of analysis
 - Heterogeneity in empirical validation approaches in economics
ABM may reflect underlying unsettled debate on philosophy of economics

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Heterogeneity of ABMs' Structure

- **Object of Analysis**
 - Qualitative - Quantitative, Single - Multiple
 - Transients - Long-run, Micro - Macro
- **Goal of Analysis**
 - In-Sample, Descriptive (most often)
 - Out-of-Sample (forecasting)
 - Prediction/Control (policy implications)
- **Methodology of Analysis: Robustness of results to**
 - micro/macro parameters
 - initial conditions (ergodicity)
 - across-run variability

Heterogeneity of ABMs' Structure

- **Modelling Assumptions**

- **Size of the space of**

- Micro/macro parameters
- Micro/macro variables
- Decision rules

- **Treatment of time/updating**

- Discrete / Continuous, Parallel / Asynchronous

- **Type of decision rules**

- Adaptive (myopic) vs. optimizing (best-reply), Deterministic vs. Stochastic

- **Type of interaction structure**

- Local vs. Global, Deterministic vs. Stochastic

- **Dynamics of decision rules and interaction structures**

- Exogenously given/changing, Endogenously selected

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Hot Issues in Empirical Validation of ABMs

- Treatment of initial conditions and parameters
 - How can we deal with all “possible worlds”? Calibration?
- Comparing ABMs’ outputs and real-world observations
 - Simulated Distributions vs. Unique Real-World Observations
- Unconditional-objects critique (Brock, 1999)
 - If many processes are able to explain the same set of SFs, what does replication of SFs add to our knowledge?
- Is available data sufficient?
 - Need for additional, more detailed microeconomics data
 - Need to validate microeconomic foundations with experimental data
- An empirical agenda
 - Searching for theory-free stylized facts
 - Looking for econometric techniques more appropriate for ABMs

Treatment of initial conditions and parameters

- Need for restricting the set of all “conceivable worlds”
 - ABMs (often) as an over-parameterized description of the “world”
 - Each point as a “conceivable” world
 - To which extent (and how) should one employ empirical data to select among all possible worlds?
- Direct vs. Indirect Calibration
 - Calibration of parameters and initial conditions on available data
 - Focusing on parameters and initial conditions that allow for replication of SFs of interest
- What can we learn from the remaining set?
 - Almost impossible to restrict to a unique world
 - Comparative dynamics exercises: Which interpretation?
 - Danger of counterfactuals in evolutionary worlds
 - “indeterminacy weakens the link between antecedent and consequent in the counterfactual” (Cowan and Foray, 2002, p. 552)

ABMs' outputs vs. real-world observations

- **Distributional objects vs. unique observations**
 - ABM provides DGP which we think real-world observations came from
 - ABM's output are distributional objects
 - Real-world observations are unique
 - “Independence” assumptions are required to transform unique empirical data in distributional objects (e.g. firm sizes or country growth-rates)
- **How can the two be compared?**
 - How can one know whether real-world observations are “typical” or “low-probability” events (with respect to the “true” DGP)?
 - ABMs: Suppose observed data are “typical” and compare them with statistics (average) of simulated data
 - Crucial to learn about the shape of the entire simulated distribution before comparing its typical outcomes with data (average may not be relevant)
 - Otherwise: Any single (low probability) simulated trace may be important to discover real-world underlying causal relationships

Unconditional Objects Critique

- **ABM as a replicator of SFs**
 - Given a set of SFs or statistical regularities there are many underlying alternative processes (DGPs) able to replicate it
 - SFs are “unconditional objects” (properties of stationary distributions) and cannot provide information on the dynamics of the process that generated them (Brock, 1999)
 - Replicating does not mean explaining
- **How can we learn on the “true” generating process?**
 - Brock (1999): Having a model that is able to reproduce a certain set of SFs is good because it always conveys information on the general forces at work and thus restricts the set of all possible generating mechanisms
 - Validating micro-economics of the model, not only macro-economic outputs (Gilbert, 2004; Duffy). A lot of detailed and reliable (empirical, experimental) data on microeconomic variables is required...
 - Looking for explanations as causal relations in simulated ABMs
output: New tools from econometrics (graphical models) may help...

An Empirical Agenda

- **Need for fresh stylized facts**
 - Many empirical regularities are theory-driven (ex: demand)
 - Theory here means “neoclassical theory”
 - Cross-section statistical properties? Dynamics?
 - Going “back to the data” and find fresh stylized facts
 - A phenomenological approach

- **Need for a new econometrics for ABMs**
 - ABMs are studied using econometric tools developed in very stationary worlds (e.g. regressions)
 - Normality vs. econometrics of heavy-tail distributions
 - Fagiolo, Napoletano and Roventini (2007)
 - How can we detect emergent properties?
 - How can we explore causal relations in ABMs?

Fagiolo, Moneta, Windrum (2007): Summary

- **Critical overview of empirical validation in ABMs**
 - When models are taken to the data, many competing approaches
- **Investigating possible reasons**
 - Methodological debate in social sciences and economics still open
 - Neoclassical models suffer from similar degree of heterogeneity
 - A lot of variety in other fields employing simulations as modeling tool
 - Heterogeneity in economics ABMs' structure
- **Crucial problems in empirical validation of ABMs**
 - Treatment of parameters and initial conditions
 - Comparing simulated distributions with unique real-world observations
 - Learning about generating mechanisms from replication of SFs
 - Need for additional data
 - An “empirical” agenda