

# Computations, Mechanisms, and Socio-Ecological Systems

A meta-theoretical appraisal of ABM

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Agent-based modeling in Ecological Economics - A useful tool or just a fancy gadget?

ESCP Europe Business School

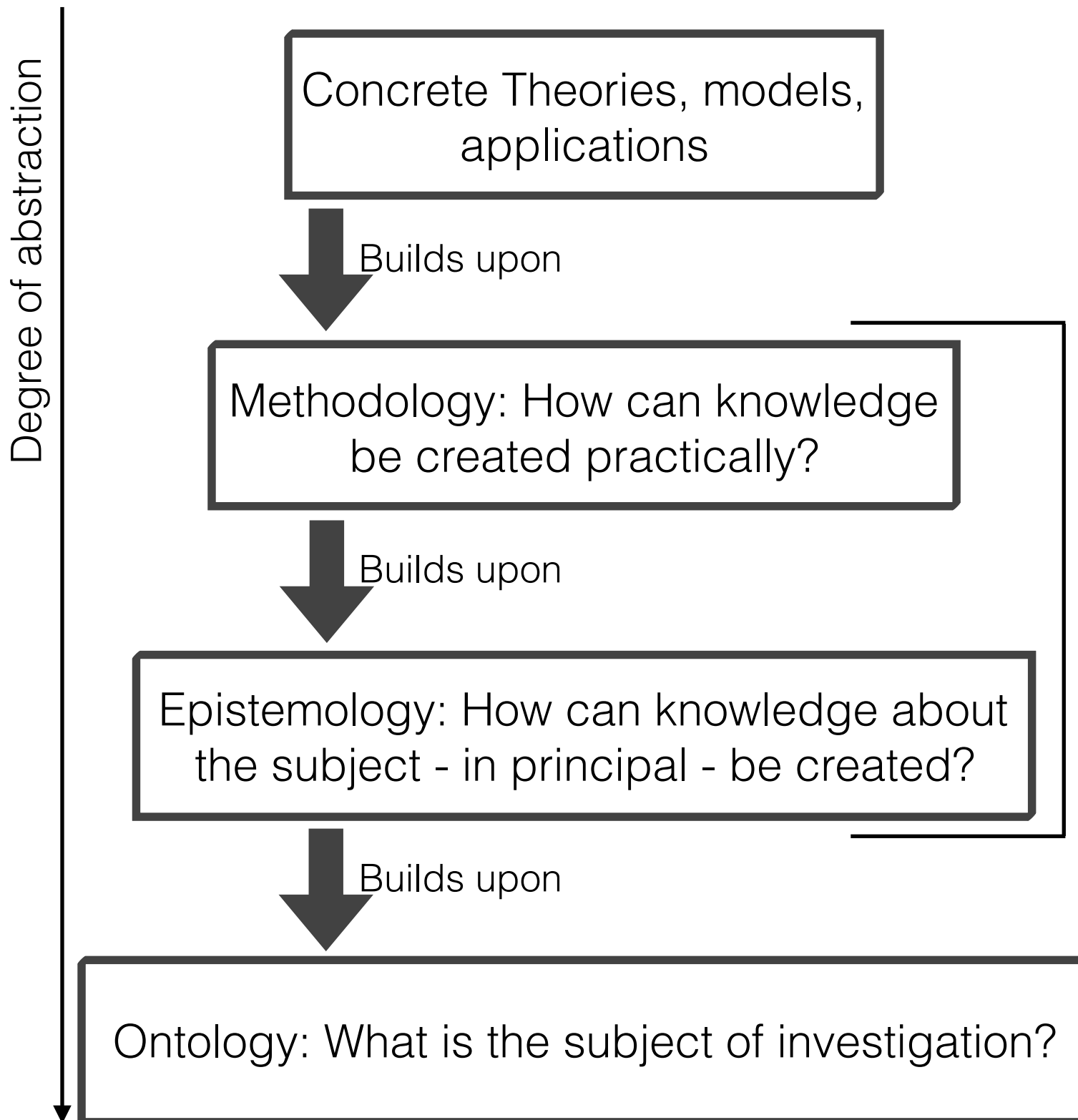
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# Outline

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- I. Motivation of a theoretical assessment of ABM
- II. An epistemological framework for ABM
- III. When ABM is an essential tool
- IV. Critical challenges for ABM to be useful
- V. Summary and outlook

# Motivation: The structure of economic research



- Judging the adequateness a *method* is a question of economic *methodology*
- The arguments put forward rely on a particular epistemology
- Discussing the value of a particular method benefits greatly from an *explicit* epistemological framework
  - We leave ontology out for now
- Here: proposal of such a framework to facilitate discussions later

# Methodological options

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- Economic methodology: which method is adequate for the problem at hand? What are the theoretical implications of different methods?
- What are the main alternatives to ABM when it comes to the study of macroeconomies and socio-ecological systems?

## **Inductive verbal reasoning**

- Theory expressed verbally
- Focus on parametric estimations
- Observation - Theorizing - Testing

## **Explorative data-mining**

- “Unprejudiced” empirics
- Focus on machine learning and non-parametric econometrics

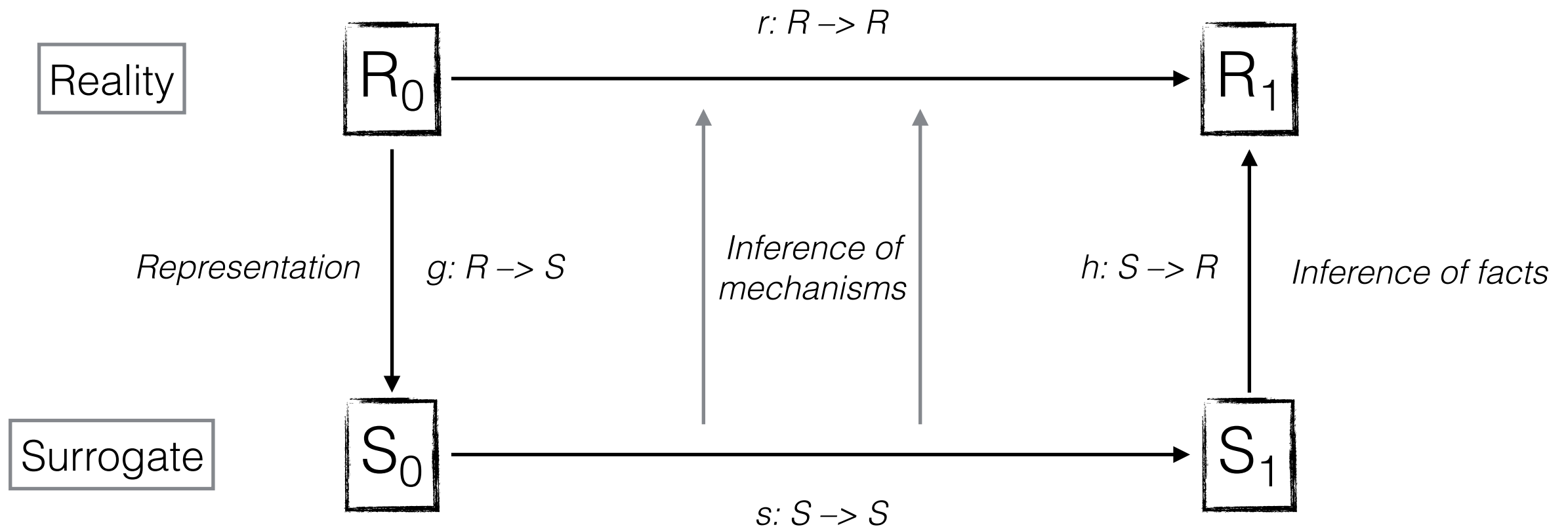
## **Applied General Equilibrium Models**

- In part. DSGE & CGE models
- Strong relation between mathematical form and empirical investigation
- Estimation/calibration of the parameters suggested by the model

- From which method can we expect most insight?
  - This requires an epistemological framework
  - Otherwise, it is not clear how ,insight‘ is to be understood

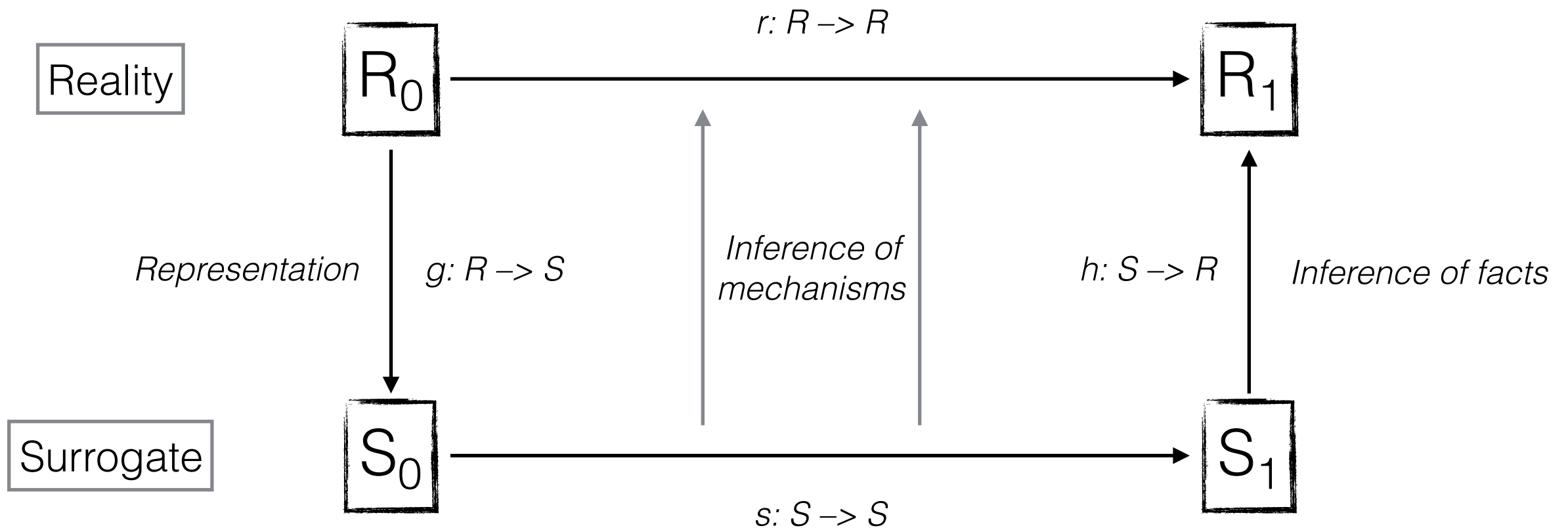
# A basic epistemological framework

Further development of Mäki's *Models as Isolations and Surrogate Systems* (MISS, Mäki 2009)



- Important distinction between *surrogates* and *substitutes* (Mäki 2009)
  - This is where *ontology* necessarily enters the stage
- What is the aim of scientific investigation in such a framework?
  - I. Isolation of the effects of particular mechanisms (i.e. inference of mechanisms)
  - II. Predicting the behavior of the SUI (i.e. inference of facts)...
    - ...based on a mechanistic understanding (c.f. Deaton 2010, Grüne-Yanoff 2016)
  - III. Investigating the interaction effects among different mechanisms

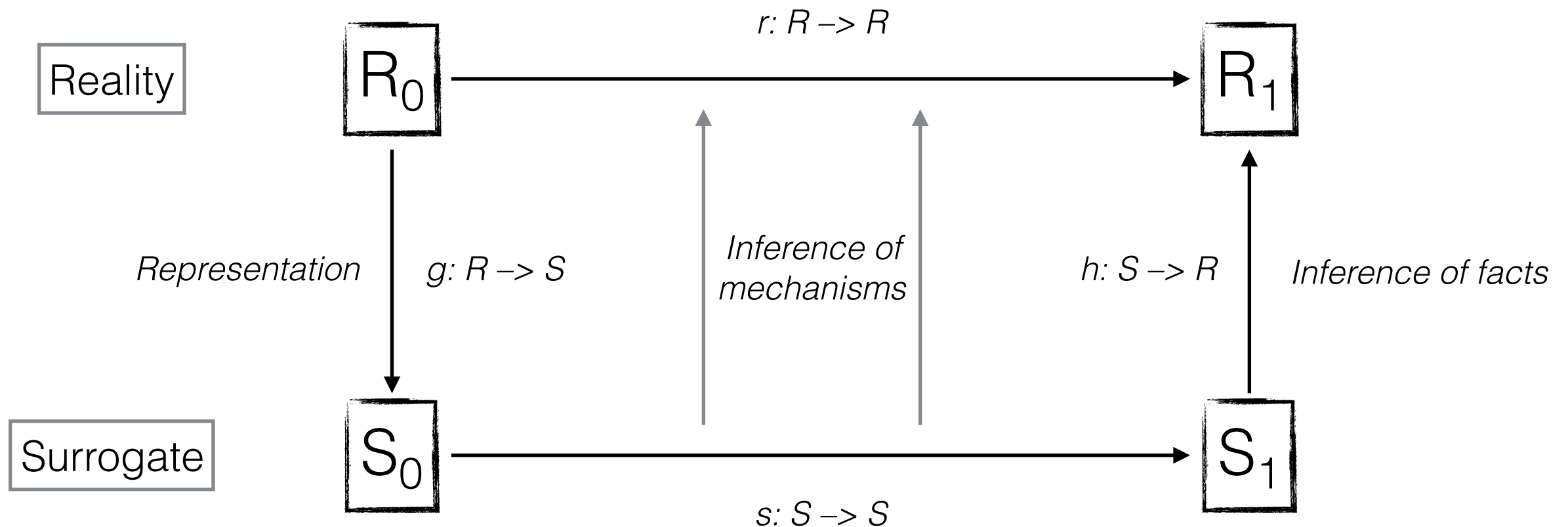
# A basic epistemological framework



	Verbal theorizing	AGE	ABM
Flexibility of complexity reduction function	++	0	+
Transparency of model exploration	0	++	+

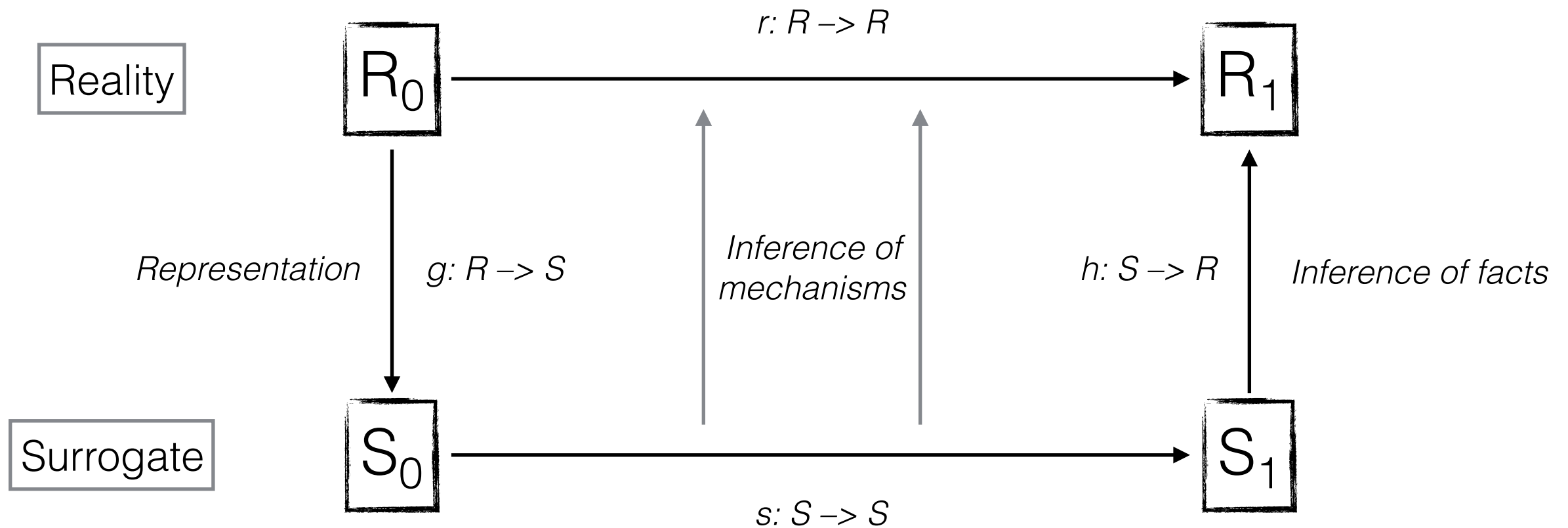
- Further different w.r.t. link to empirical work
  - AGE and ABM allow direct consideration
  - Verbal models use empirics indirectly

# A basic epistemological framework



- Considering the flexibility on the side of the assumptions (‘representation’), and the rigor of the model exploration, ABM are somehow the *golden (?) middle* between analytical GE models and verbal theorizing
- The combination of a flexible mean of complexity reduction and a 100% deductive model corpus represents a *distinctive feature* of ABM compared with its alternatives
  - 100% deductive if numerical algorithms understood as logical rule of inference, as common in econometrics and AGE literature
- Additional feature: affinity to *constructive* mathematical reasoning (c.f. the *generative social sciences* of Epstein (2007))

# A basic epistemological framework



- Whether an ultimate identification of mechanisms is possible remains unclear...
  - ...but perfect prediction is certainly not feasible (c.f. Laplace's demon)
  - For progress, both representation and and resemblance part of models must advance
- Calls for realism on several ontological levels at once
- May even suggest moving beyond Occam's razor as a discrimination tool
  - Alternative: *deepness of an explanation* (Bunge 1997, Gräbner & Kapeller 2016)



# ABM vs. GET models: Taking the Lucas critique seriously

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- Reference point for DSGE and CGE: stagflation in the 70s, partly due to misleading policy advice based on the *Cowles Commission approach* (see e.g. Moneta 2005)
- Lucas critique (1976): necessity for sound micro foundations of economic analysis and consideration of expectations
  - Methodological consequence: Use of *rational* expectations (RE)
- Focus on RE reduces the degrees of freedom of the complexity reduction function
  - No real micro calibration of assessment of intermediate results, e.g. Euler equation
  - Features such as true uncertainty and the corresponding heuristics (Gigerenzer et al.) are excluded from analysis
  - Cannot provide surrogate for situations in which such features are *essential*
- Due to focus on representative agents prohibits the study of particular mechanisms, including aggregation mechanisms (c.f. SMD results, see also Fagiolo & Roventini (2012))
- ABM as the ‚better‘ answer to the Lucas critique?!

# ABM vs. verbal models: On consistency and surprise

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- All verbal model do reduces the complexity of the real world just as as every formal model
- They provide a very flexible form of complexity reduction, but:
  - The deductions within verbal models are potentially fuzzy and may entail (unrecognizable) creative steps
  - Investigation of the combination of mechanisms can be difficult
  - In contrast to verbal models, ABM can cause *surprise* (Roos 2016)
  - Without formalization the link between data and theory is less stringent
- Verbal models usually use the language ‚English‘
  - Good to describe some things...but bad when it comes to other
  - There are examples on which it is easier to talk in the language of ABM

# The benefits of an algorithmic language: computations

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- ABM provide a different language than real analysis or English
  - Different set of vocabulary, e.g. that of a *computation*
- Directly relate to the problem of the *complexity* of decision problems
  - Every economic agent faces decision problems
  - Since an optimal computation of these problems is not feasible, agents develop *heuristics*
    - This includes the computation (or: estimation) of rational expectations
  - What if the way humans use heuristics carried explanatory power?
- Essence of Newell & Simon (1972) was that humans think *algorithmically*
  - Vantage point for a modern account of heuristics (e.g. Gigerenzer & Gaissmaier 2011)
  - Assumption of rationality eliminates any reasonable consideration of computations

# ABM and socio-ecological systems

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- What are *essential properties* of socio-ecological systems? What are the corresponding methodological demands?
  - 1) Heterogeneity among the social agents, other-regarding preferences, relevance of local institutions and communication (Ostrom et al. 1992)
    - ➔ Way people make their decision becomes important (c.f. computations)
  - 2) Coupling of social and bio-physical dynamics, complex decision problems
    - ➔ Resulting true uncertainty for the decision making agents and application of heuristics
  - 3) Spatial settings matter, e.g. infrastructure, access to resources, land use, effect on behavior in dilemma situations
    - ➔ Necessity to account for interaction topology via explicit networks
- In many empirically informed cases, ABMs will be necessary (see also Janssen & Ostrom 2006)

# Summary: the theoretical pros of ABM

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- Compared with verbal theorizing and analytical GET
  - ...*golden (?) middle* between adequate representation of the system investigated...
  - ...and transparent model exploration
- Allows a *mechanism-based* explanation of reality
- Provides a language that is sometimes richer than English (example: computations)
- Allows a reasonable coupling of theoretical and empirical work
  - Important distinction to machine learning or non-parametric econometrics

# Critical challenges for ABM

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- There is a number of potential methodological shortcomings of ABM

## I. Intransparency

- ➔ What is the cause for a particular model dynamics?
- ➔ Need for adequate model *verification*

## II. Overparametrization and ad-hoc specification

- ➔ Why choosing exactly this kind of decision making?
- ➔ Need for adequate model *validation*

## III. Communication of the model

- ➔ Journal space is scarce and (most) economists have a fetish for particular equations...
- ➔ Need for ‚standard procedures‘ (?)

- The flexibility of ABM is often called a major weakness: potentially ad-hoc

- ➔ Here: stress the potential for adequate validation on different ontological levels

# An ongoing challenge: validating ABM

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- Exceptional property of ABM: flexibility but concreteness of the complexity reduction function and mechanisms in the model
  - Flexibility on various ontological level as distinctive feature of this method
  - „Dis“advantage: forces us to be explicit
- Potential answer: Empirical validation...
  - ...on various ontological levels
  - This is distinctive for ABM
- Status quo: Important progress for the macro calibration of ABM:
  - Quantitative approaches include Werker-Brenner approach (Brenner & Werker 2007), history-friendly modeling (Malerba et al. 2016), ...
  - On individual level: dominance of qualitative and anecdotal evidence
- To exploit the full potential of ABM we require tools for the *simultaneous* validation of micro and macro level of the ABM
  - Promising suggestions: Guerini & Moneta (2016)

# Summary and outlook

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- Is ABM necessary for the problem at hand?
  - The answer to this question always refers to an epistemological framework
- There are situations in which ABM are an indispensable tool to understand certain systems because...
  1. ... the essential properties of the system under investigation are such that they cannot be captured in an analytical model
  2. ... the algorithmic language of ABM allows a realist approach to phenomena otherwise only understood through narrow instrumental approaches
  3. ... the implications of mechanisms or their particular combination cannot be conjectured verbally
- Full potential of (macro) ABM requires progress with validation procedures
- But also proof-of-concept ABM have a number of desirable epistemological properties
  - Close relationship to empirical results from within and outside economics
- ABM is not a cure-all - but many of its weaknesses also bear potential



# Thank you for listening!

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