Agent-Based Modelling & NetLogo

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(using slides from)
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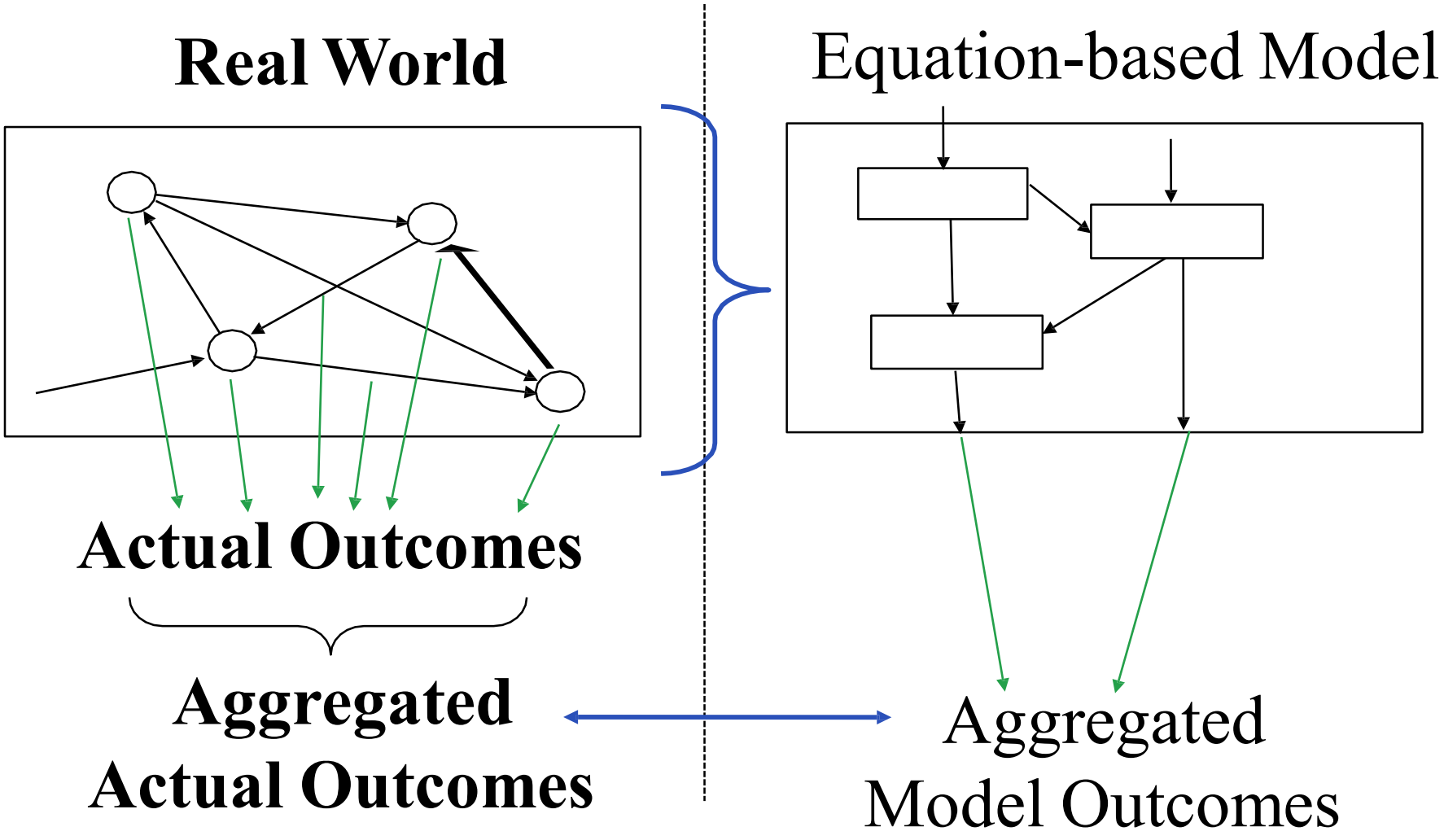
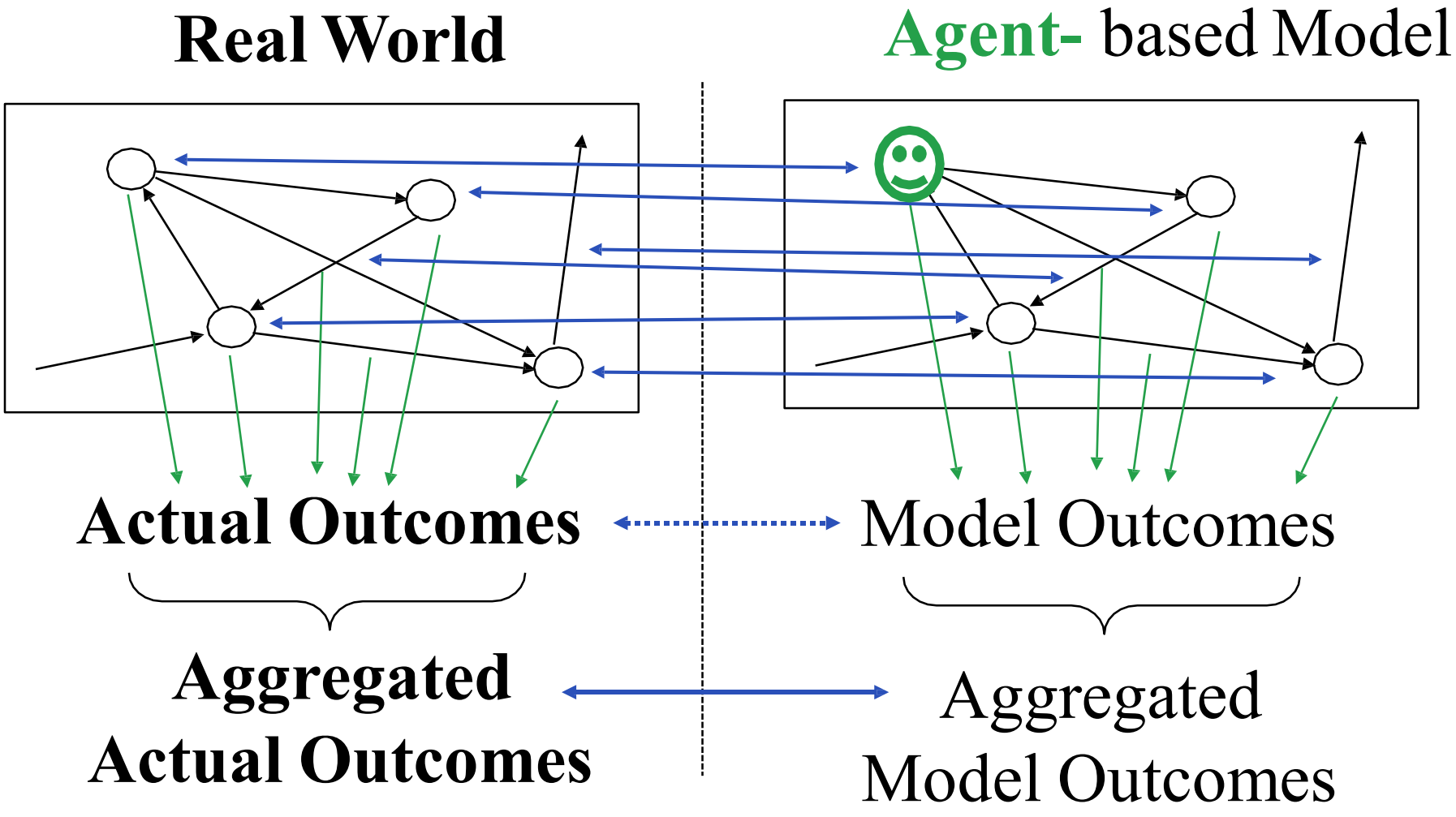
Society is Complex!

- This may not be a surprise to many of you..
- …but in the sense of complexity science it means that significant global outcomes can be caused by the interactions of networks of individuals
- The outcomes are not modellable if you do not model interactions between individuals or model only the interaction of global variables…
- …and if you try to model it in these ways, you will often be caught out by *surprises*
- Agent-based simulation allows the exploration of such surprises but it is still a maturing field

Equation-based or statistical modelling

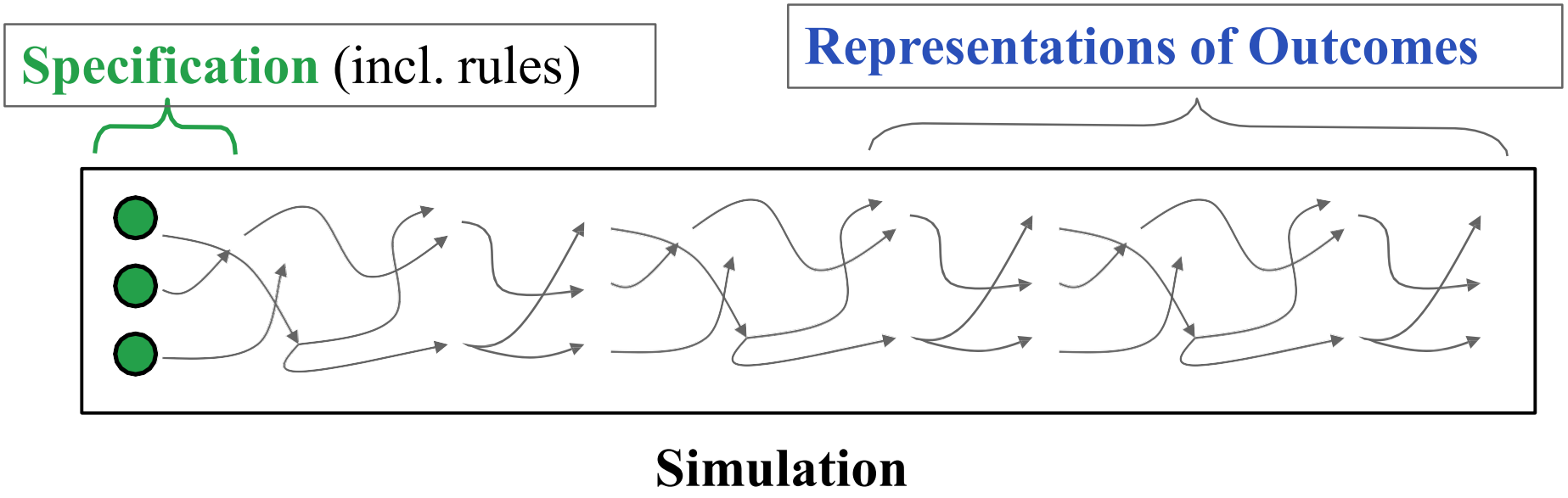


Individual- or Agent-based simulation



What happens in ABSS

- Entities in simulation are decided on
- Behavioural Rules for each agent specified (e.g. sets of rules like: if *this has happened* then *do this*)
- Repeatedly evaluated in parallel to see what happens
- Outcomes are inspected, graphed, pictured, measured and interpreted in different ways



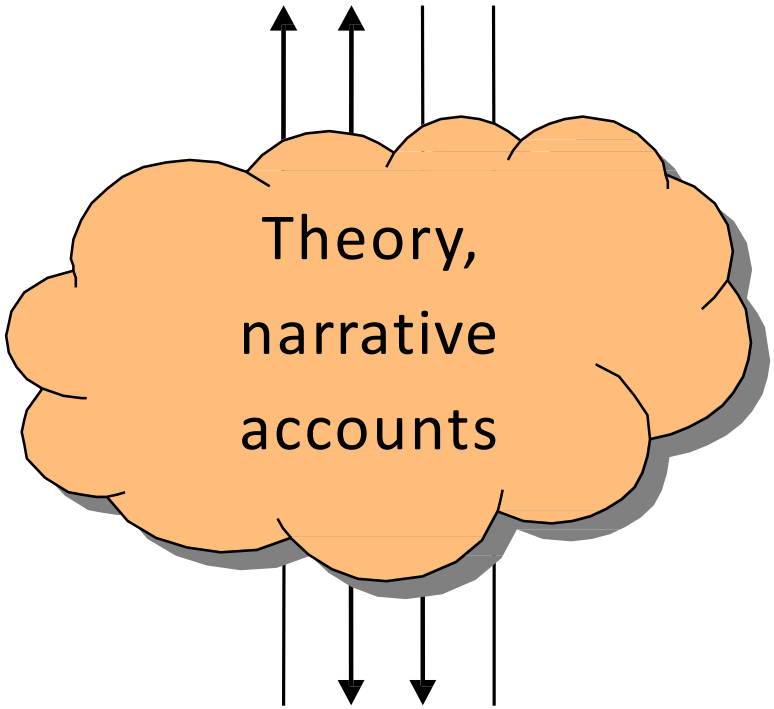
Characteristics of agent-based modelling

- Computational description of process
- Not usually analytically tractable
- More specific…
- … but assumptions are less ‘brave’
- Detail of unfolding processes accessible
  - more criticisable (including by non-experts)
  - but can be more convincing than is warranted
- Used to explore inherent possibilities
- Validatable by a variety of data kinds…
  - but needs LOTS of data to do this
- Often very complex themselves

Micro-Macro Relationships

Macro/
Social data

Social, economic surveys; Census



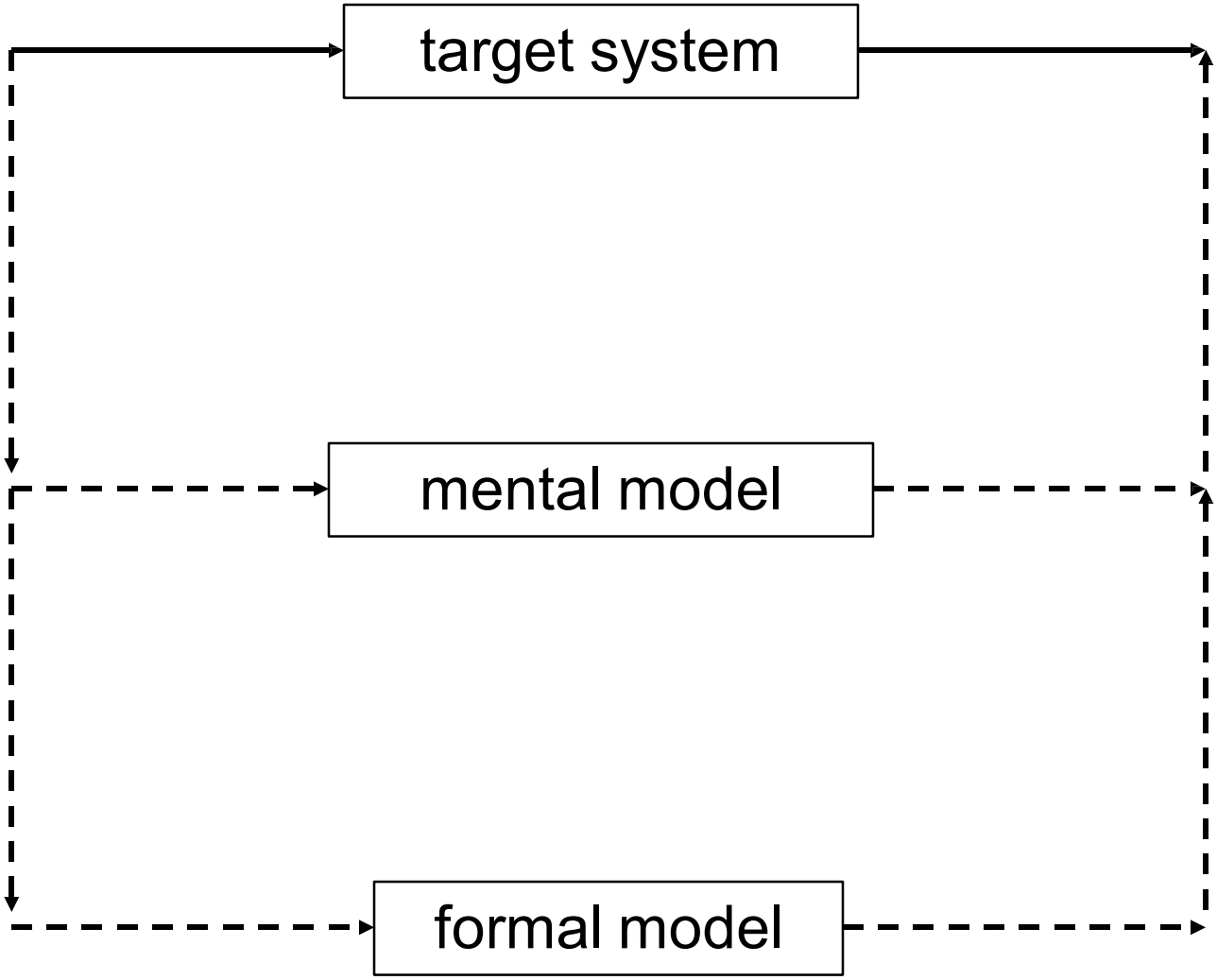
Micro/
Individual data

Qualitative, behavioural, social psychological data

Choosing Simulation Techniques

- Every simulation technique has pros and cons
- The *hardest* decision is when to use which approach (or how to combine approaches)
- Analytic approaches rely on their formulation being simple enough to be solvable (or, in practice, they use simulation anyway)
- Statistical approaches rely (in different and subtle ways) on the representation of *noise* as random – they will miss surprises in their projections
- Agent-based approaches are complex, require lots of data and do not give probability forecasts
- Simplicity is no guarantee of truth or generality

Meaning from intermediate abstraction (often implicit)

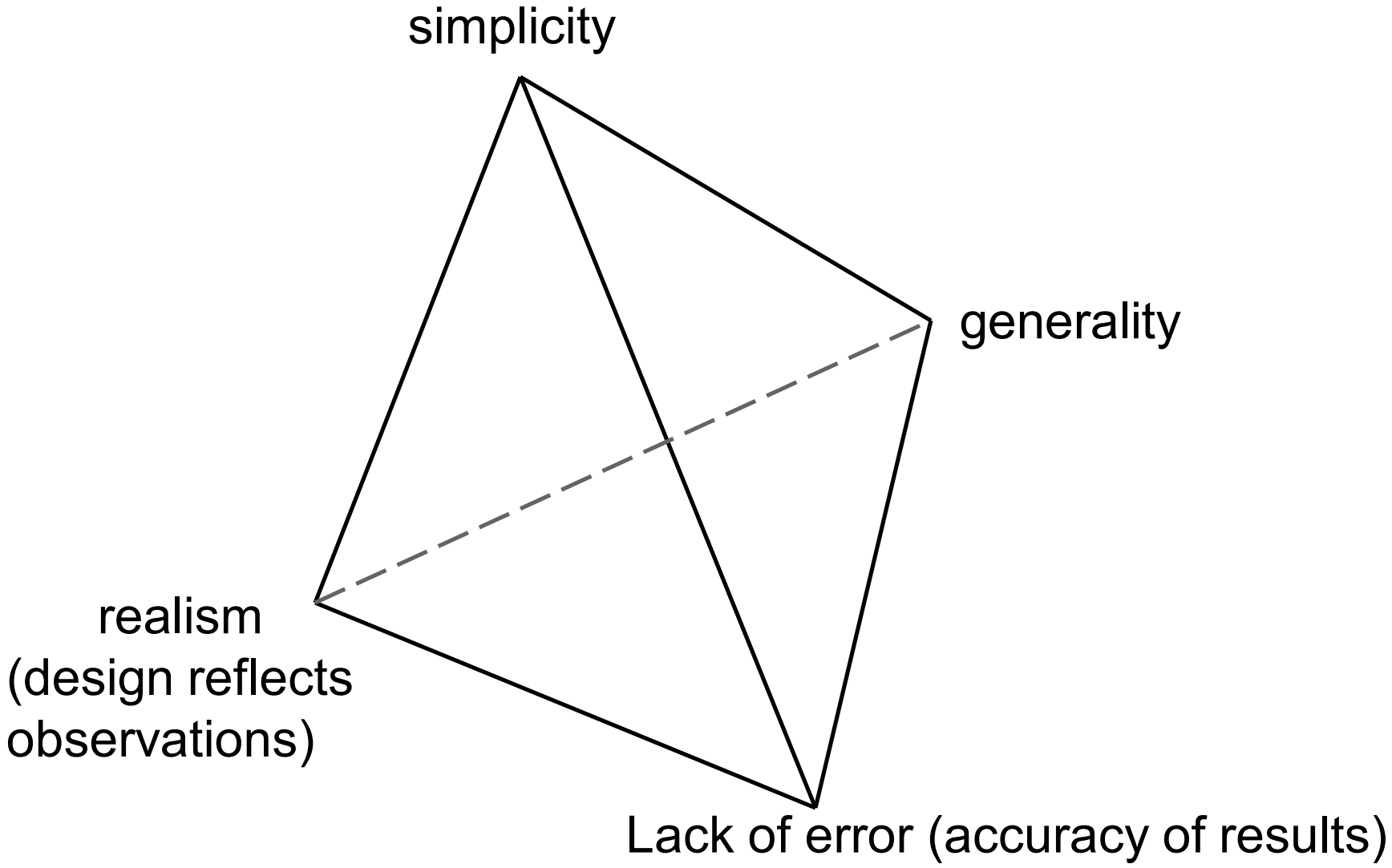


(Meaning)

In Vitro vs In Vivo

- In biology there is a well established distinction between what happens in the test tube (*in vitro*) and what happens in the cell (*in vivo*)
- *In vitro* is an artificially constrained situation where some of the complex interactions can be worked out…
- ..but that does not mean that what *happens in vitro* will occur *in vivo*, since processes not present *in vitro* can overwhelm or simply change those worked out *in vitro*
- One can (weakly) detect clues to what factors might be influencing others *in vivo* but the processes are too complex to be distinguished without *in vitro* experiments

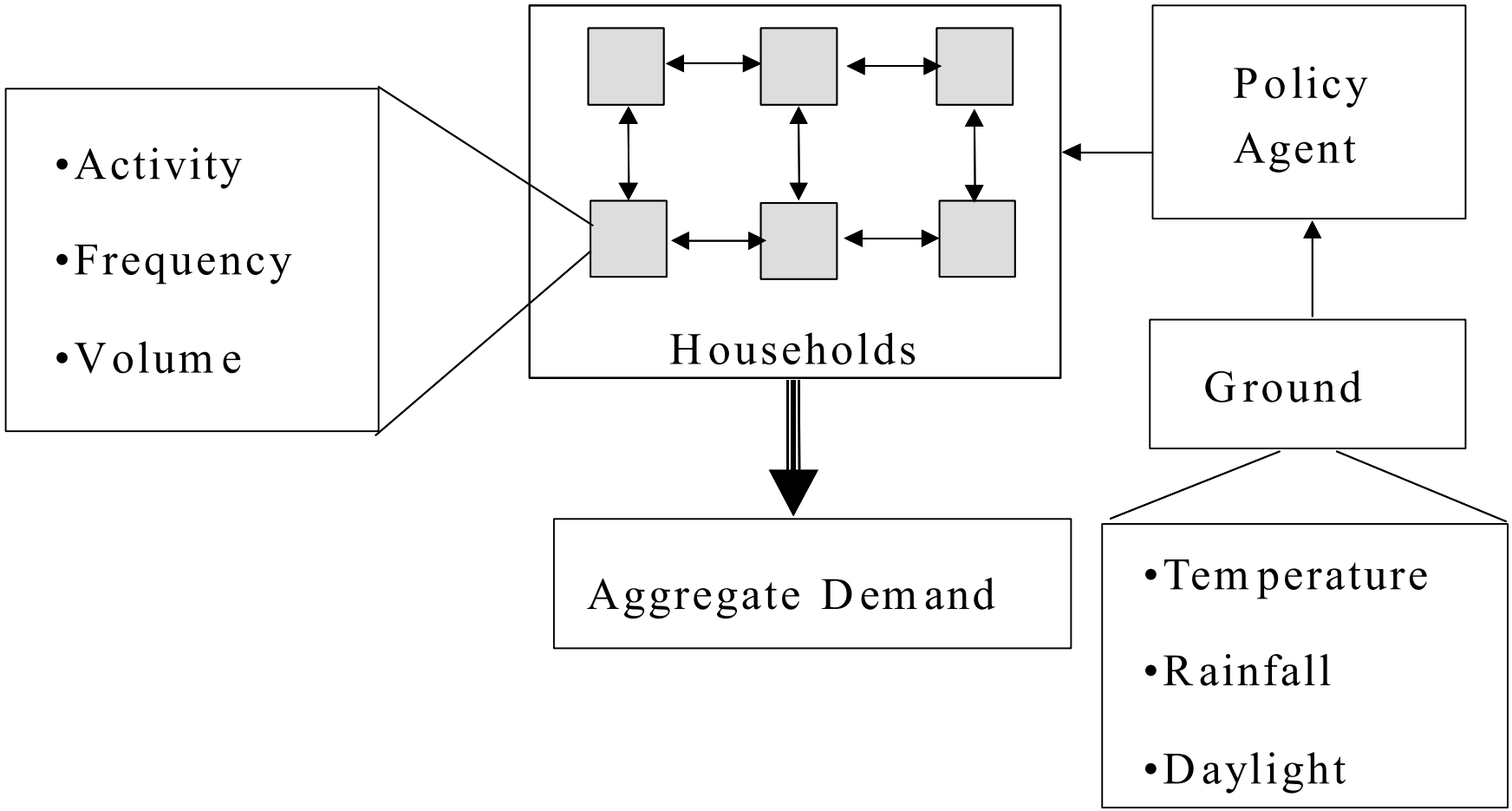
Some modelling trade-offs



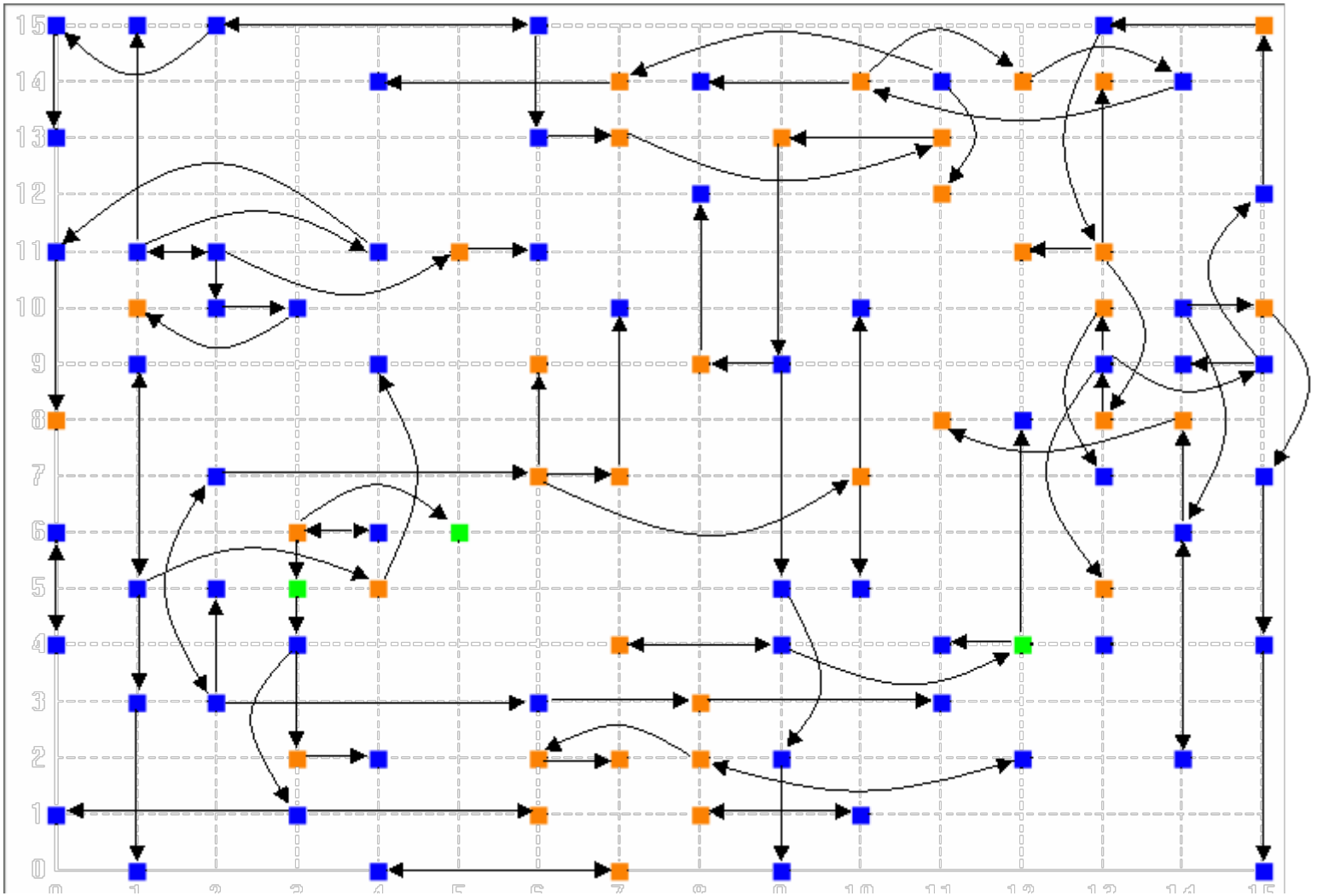
Example: A *model of social influence and water demand*

- Part of a 2004 study for EA/DEFRA, lead by the Stockholm Environment Institute (Oxford branch)
- Investigate the possible impact of social influence between households on patterns of water consumption
- Design and detailed behaviour from simulation validated against expert and stakeholder opinion at each stage
- Some of the inputs are real data
- Characteristics of resulting aggregate time series validated against similar real data

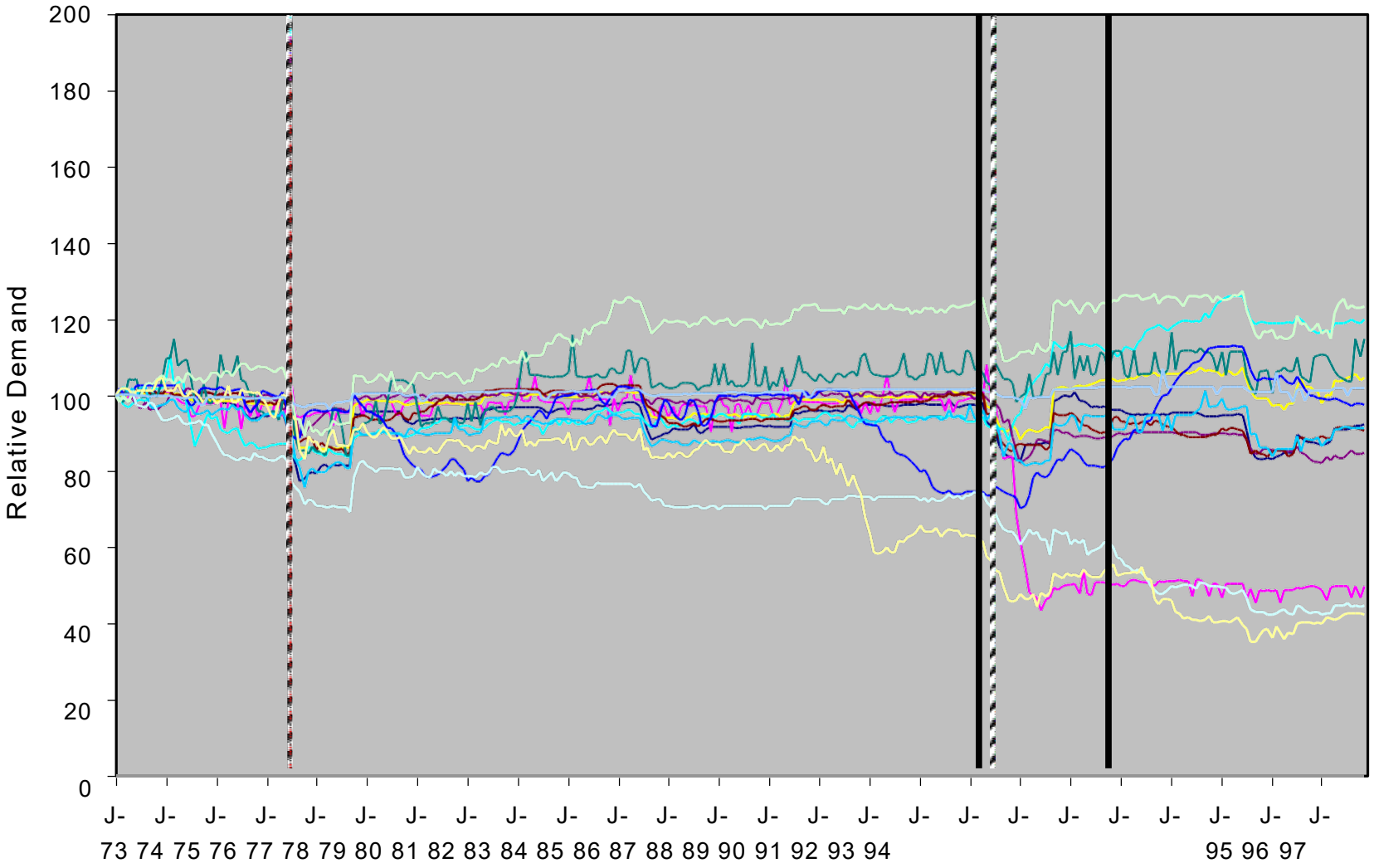
Simulation structure



Some of the household influence structure



Example results: relative aggregate domestic demand for water (1973 = 100)



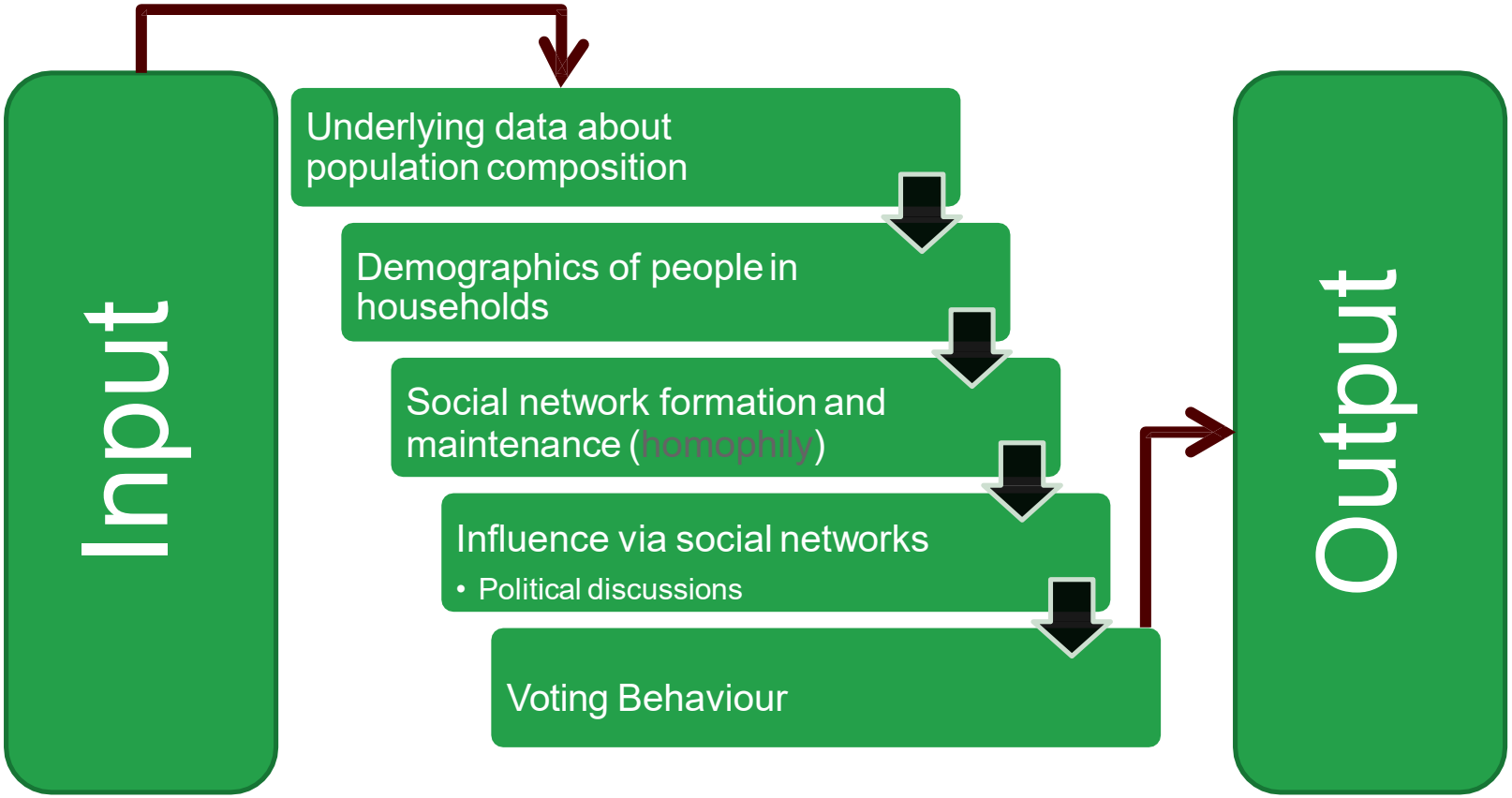
Conclusions from Example

- The use of a concrete descriptive simulation model allowed the detailed criticism and, hence, improvement of the model
- The inclusion of social influence resulted in aggregate water demand patterns with many of the characteristics of observed demand patterns
- The model established how:
  - processes of mutual social influence could result in differing patterns of consumption that were self-reinforcing
  - shocks can shift these patterns, but not always in the obvious directions
  - the importance of introduction of new technologies

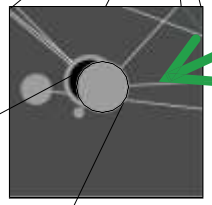
Example 2: Voting behaviour

- Institute for Social Change & Theoretical Physics Group, ***University of Manchester***
- Centre for Policy Modelling, ***Manchester Metropolitan University***

Overall Structure of Model

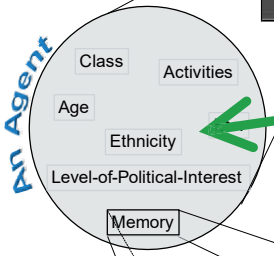


Changing personal networks over which social influence occurs

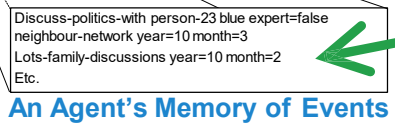


A Household

Composed of households of individuals initialised from detailed survey data



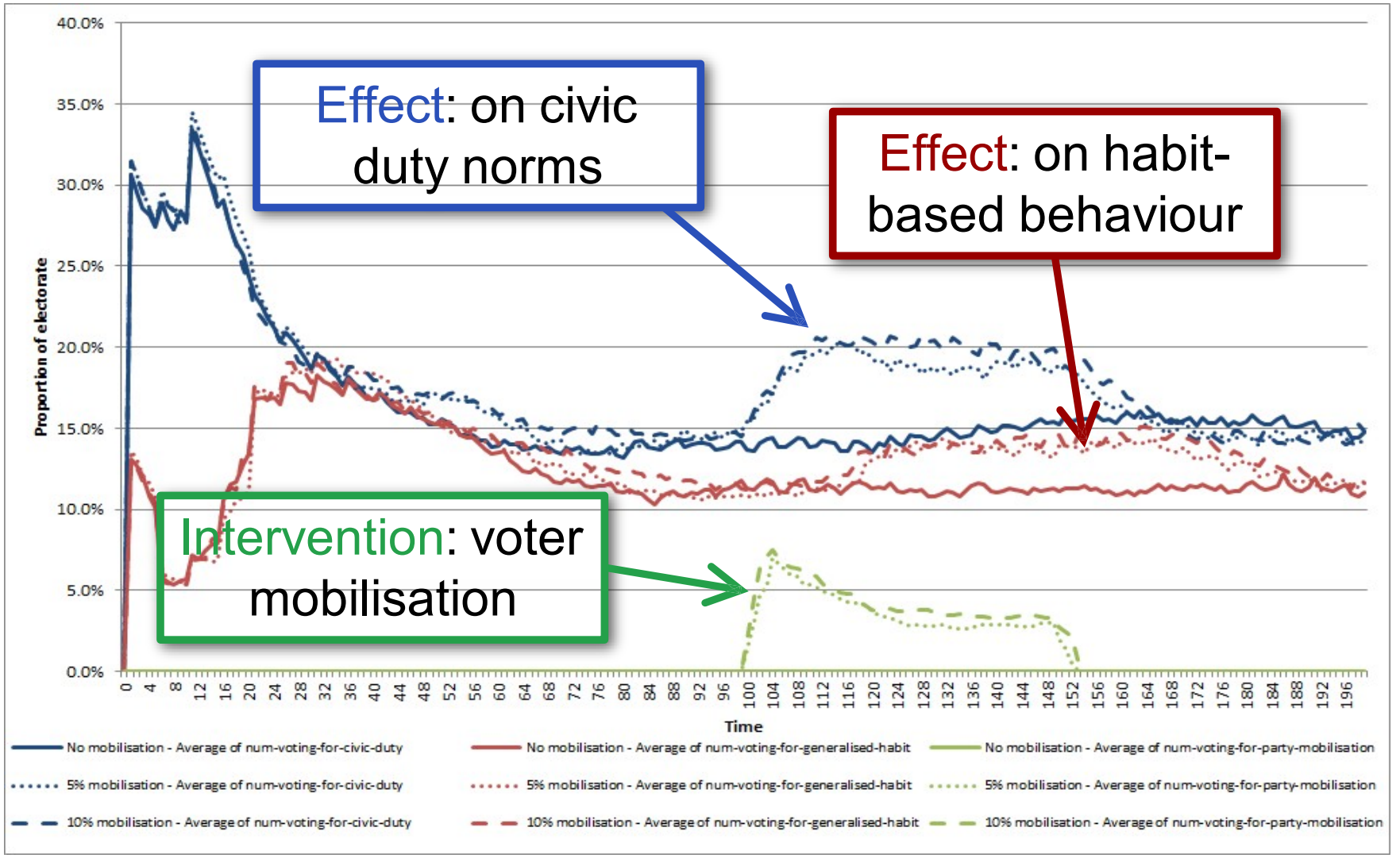
Each agent has a rich variety of individual (heterogeneous) characteristics



An Agent's Memory of Events

Including a (fallible) memory of events and influences

Example Output: why do people vote (if they do)



Possibilistic vs Probabilistic

- The idea is to map out some of the *possible* social processes that may happen
- Including ones one would not have thought of or ones that have already happened
- The global coupling of context-dependent behaviours in society make projecting probabilities problematic
- Increases understanding of why processes (such as the spread of a new racket) might happen and the conditions that foster them
- Complementary to statistical models

Role of ABM in Policy Assessment

- ABMs are good for analysing risk – how a more standard model/prediction might go/be wrong
- That is, testing the assumptions behind simpler models (statistical, discrete event, system dynamic, etc.)…
- …so exploring the possible deviations from their forecasts
- In other words, showing some of the possible surprises that could occur (but not all of them)
- To inform a risk analysis that goes with a forecast
- Can be used for designing early-warning indicators of newly emergent trends

ABSS Advantages

- ABSS allows the production and examination of possible complex outcomes that might emerge
- It does not need such strong assumptions (that analytic approaches require) to obtain results
- It allows the indefinite experimentation and examination of outcomes (*in vitro*)
- It aids the integration and use of a wider set of evidence, e.g. very open to stakeholder critique
- It suggests hypotheses about the complex interactions in observed (*in vivo*) social phenomena
- So allowing those 'driving' policy to be prepared, e.g. by implementing 'early warning systems'
- Can be complementary to other techniques

ABSS Disadvantages

- It does not magically tell you what will happen
- Are relatively time-consuming to construct
- It can look more convincing that is warranted
- Understanding of the model itself is weaker
- It needs truck loads of data for its validation
- It gives possibilities rather than probabilities
- Fewer good practitioners around
- Not such a mature field

To Learn More

- *Simulation for the Social Scientist*, 2nd Edition. Nigel Gilbert and Klaus Troitzsch (2005) Open University Press. http://cress.soc.surrey.ac.uk/s4ss/
- *Simulating Social Comlexity* – *a handbook*. Edmonds & Meyer (eds.) (2013), Springer.
- *Journal of Artificial Societies and Social Simulation*, http://jasss.soc.surrey.ac.uk
- *European Social Simulation Association*, http://essa.eu.org
- *NetLogo*, a relatively accessible system for doing ABM http://ccl.northwestern.edu/netlogo
- *OpenABM.org*, an open archive of ABMs, including code and documentation