Models, mathematics and meaning in interdisciplinary research

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Thesis

- Interdisciplinary research needs an arena in which to frame and settle differences – a territory to contest and negotiate over - if it is to work properly.
- Modelling (and model theory*), because of its instrumental nature, its lack of codification, its loose relationship with epistemologies, theories, methods and data, provides a set of concepts regarding the way we represent the world which are sufficiently flexible and general to form a territory to be contested and negotiated over in interdisciplinary research.

* I use the term ‘Model theory’ (small ‘t’) to refer to the collective works of Casti, Rosen, Morgan, Cartwright, et al of which Model Theory (set theory) is one strand.
Interdisciplinary

- Bringing together disciplines to focus on a mutually agreed subject or problem which lies between, or spans, these disciplines.

- Requires:
  - More than just bringing disciplines together
  - Accepting epistemological differences
  - Relinquishing control over knowledge
  - Creating new knowledge by collaboration
  - A common conceptual framework
  - Shared terminology, mental images and goals
  - Deliberate ‘knowledge boundary’ negotiation
  - Mutual trust
Interdisciplinary needs commonality

• 'We found] two types of communities: scientists grouped together by similarity either of research topic or of methodology. It is not surprising to see communities built around research topics; we expect scientists to collaborate primarily with others with whom their research focus is closely aligned. The formation of communities around methodologies is more interesting, and may be the mark of truly interdisciplinary work. (Girvan and Newman, 2002 p.6)
Models as Mediators
(Morgan and Morrison, 1999)

• '...models mediate between theory and the world.' (p.242).
• models act as quazi-autonomous agents and are not reducible to either theory or the data.
• Four functions of models:
  – Construction: bringing together elements from theories, models and the data to build a model.
  – Instruments of investigation: for theory testing, theory building, and for highlighting what and how to measure.
  – Representation: of the system for understanding and projection.
  – Learning: focusing on limitations and where to focus further work.
Agreeing a definition of ‘model’

- “Our viewpoint is that the study of natural systems begins and ends with the specification of observables describing such a system and a characterization of the manner in which these observables are linked.”
  – (Casti 1992, p.2)

- “The only way in which we can have scientific contact with the world…is through actions involving selection, abstraction, and generalisation, which are always executed within some theoretical framework or disciplinary matrix….”
  – (Ruttkamp 2002 p.17)
Models’ territory of representation

• Observables
• Relations
• Subject
  – ‘Reality’
  – 'Abstractions'
  – 'Perceptions'
• Uncertainty (Exogenous vs endogenous – accuracy vs precision)
  – Instrument error
  – Aleatory uncertainty
  – Epistemic uncertainty

• Type
  – Theoretical
  – Phenomenological
• Model subject
  – Individuals
  – Populations
• Action
  – Causation
  – Correlation
• Solution
  – Propagation
  – Optimisation
Modelling home energy use - The CaRB project
(EHCS ‘96, n = 3,676, Mean ~30,000 kWh)
Epistemic uncertainty: Competing theories of Home energy use

- Sociological theories
  - Socio-technical systems theory; Actor network theory
- Psychological theories
  - Attitude-behaviour models
- Economic
  - Rational action models
- Physical
  - Building thermal simulation
- Different sets of variables
- Different relationships between variables
‘Buildings use energy’ (Engineers)
Physical modelling assumptions

• Crudely, physical models often assume the following:
  – Modelling specific instances – i.e. individuals or 'archetypes' - not populations.
  – No variable instrument uncertainty - i.e. instruments measure perfectly.
  – No variable aleatory uncertainty (because specific instances are modelled).
  – No variable relationship uncertainty. - i.e. the relationship between any two variables is fixed and hardwired into the model (e.g. spreadsheet models).
  – No epistemic model uncertainty - i.e. it is assumed that the right variables are wired together. This is usually dictated by theory.

• Uncertainty is entirely exogenous - you are: modelling a specific instance; with a known & fixed model structure; with fixed variable relationship strength; no variable uncertainty; and no instrument error.

• Modelling each additional variable increases explanatory power and completeness.
‘People use energy’ (Social scientists)
Statistical modelling assumptions

• Crudely, statistical models can relax most of these assumptions.
  – Modelling populations
  – Models include variable instrument uncertainty
  – Models include variable aleatory uncertainty (because populations are modelled)
  – Variable instrument & aleatory uncertainty are indistinguishable in the data
  – Model variable relationship uncertainty - i.e. the strength of the relationship between variables depends on the strength of your data and can change.
  – Model epistemic model uncertainty - i.e. there are many ways to wire the variables together – and we don’t necessarily know which is best. This leads to the concept of a ‘model space’ – i.e. a set of models to chose between.

• Uncertainty is largely endogenous - ‘reality’ is buried indistinguishably in a sea of uncertainty within your model.

• Measuring each additional observable carries an opportunity cost – so for given resources, you don’t measure as many variables as you can.
One solution: model home energy use as a joint distribution over a set of variables.
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- **Further information:**
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