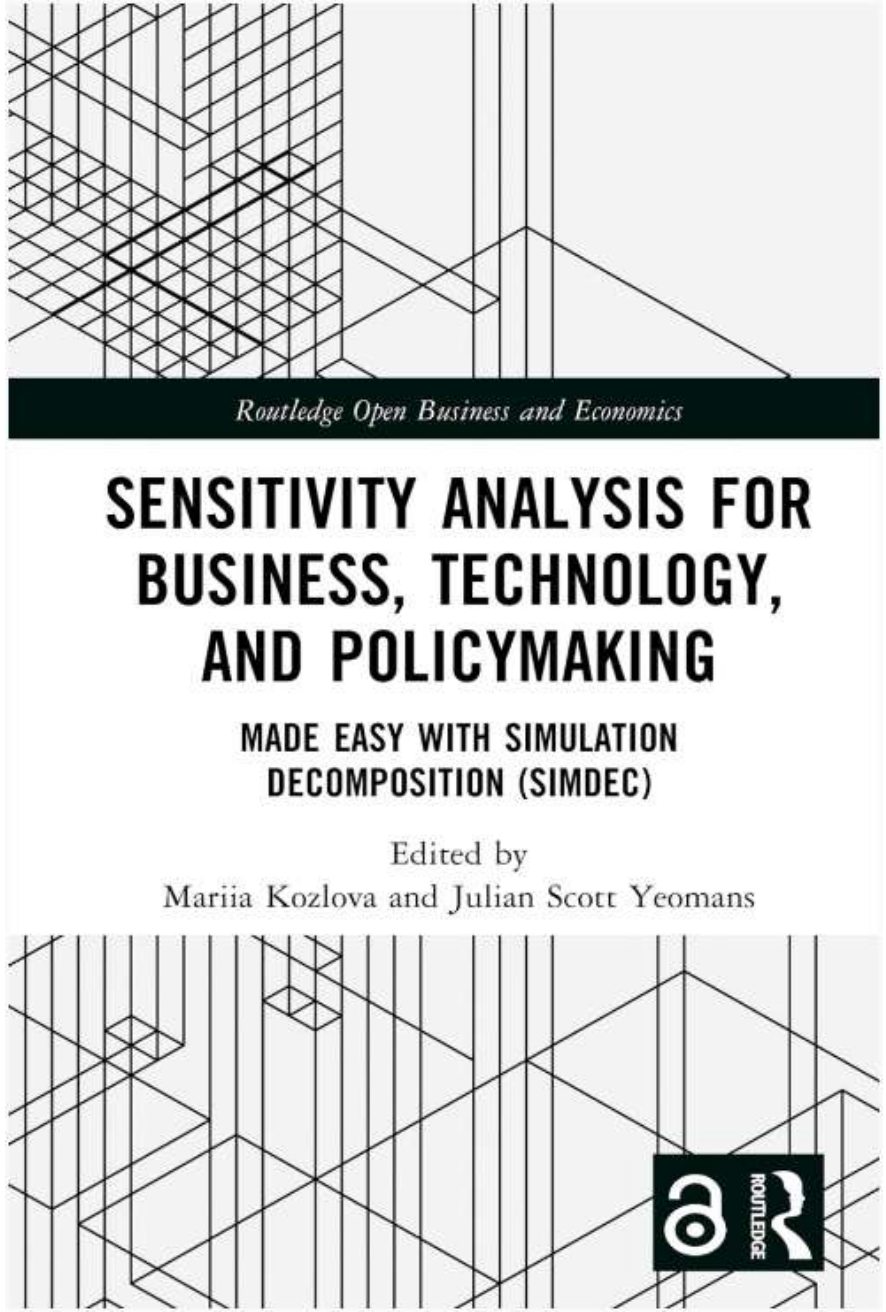
# Preface to

Virtual, December 3rd 2024

Andrea Saltelli

upf. BARCELONA SCHOOL OF MANAGEMENT

UNIVERSITAS BERGENSIS



Andrea Saltelli

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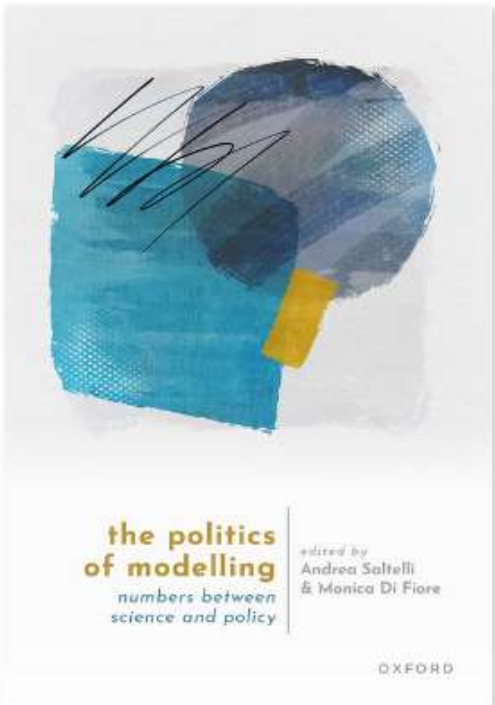



## Latest paper

We reflect on the development of digital twins of the Earth, which we associate with a reductionist view of nature as a machine. We contest the utility of digital twins for addressing climate change issues and discuss societal risks associated with the concept, including the twins' potential to reinforce economicism and governance by numbers, emphasizing concerns about democratic accountability...

**Last book**

*"A long awaited examination of the role —and obligation —of modeling."*
**Nassim Nicholas Taleb** , Distinguished Professor of Risk Engineering, NYU Tandon School of Engineering. Author, of the 5 -volume series Incerto.

•••

*"A breath of fresh air and a much needed cautionary view of the ever-widening dependence on mathematical modeling."*
**Orrin H. Pilkey**, Professor at Duke University's Nicholas School of the Environment, co-author with Linda Pilkey-Jarvis of Useless Arithmetic: Why Environmental Scientists Can't Predict the Future, Columbia University Press 2009.

•••

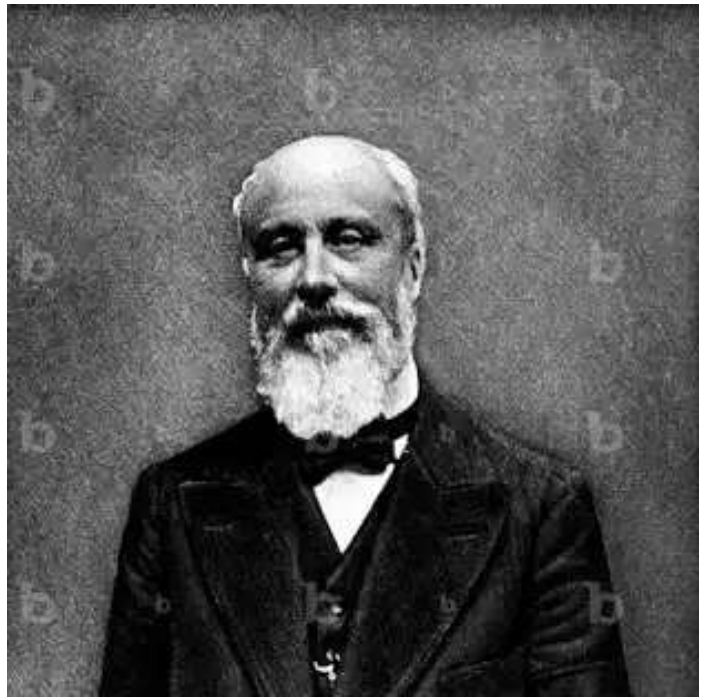
**Mastodon Toots** by
@AndreaSaltelli

AndreaSaltelli
2024/11/23 16:47
Presentation Responsible Modelling and Forecasting, Course SGD 207, Realfagbygget, Bergen, November 19, 2024, Andrea Saltelli. Slides: andreasaltelli.eu/file/reposit

View on mstdn.social

"… inferences from mathematical models of phenomena to real physical applications must also be demonstrated to be approximately correct when the assumptions of the model are only approximately true" [1]

# Pierre Duhem (1861–1916) and his 'Principle of stability'



[1] S. C. Fletcher, 'The Principle of Stability', Philosopher's Imprint, vol. 20, no. 3, 2020, Accessed: Sep. 08, 2024. [Online].

# Models are fragile

Duhem's principle of stability [1], and the occurrence of either Butterfly [2] or Hawkmoth effects [3].

The accumulation of parametric error in a model, the so called uncertainty cascade [4], that is the subject of global sensitivity analysis studies [5].


[1] S. C. Fletcher, 'The Principle of Stability', Philosopher's Imprint, vol. 20, no. 3, 2020, Accessed: Sep. 08, 2024. [Online].
[2] H. G. Schuster, Deterministic Chaos: An Introduction, 2nd Rev edition. Weinheim: Vch Pub, 1998.
[3] E. Winsberg, 'Appendix: Structural Stability and the "Hawkmoth Effect"', in Philosophy and Climate Science, Cambridge: Cambridge University Press, 2018, pp. 232–246. doi: 10.1017/9781108164290.016.
[4] M. Christie, A. Cliffe, P. Dawid, and S. S. Senn, Simplicity, Complexity and Modelling. Wiley, 2011.
[5] A. Saltelli et al., 'Five ways to ensure that models serve society: a manifesto', Nature, vol. 582, pp. 482–484, 2020.

"I have proposed a form of organised sensitivity analysis that I call 'global sensitivity analysis' in which a neighborhood of alternative assumptions is selected and the corresponding interval of inferences is identified.
Conclusions are judged to be sturdy only if the neighborhood of assumptions is wide enough to be credible and the corresponding interval of inferences is narrow enough to be useful."

Edward E. Leamer, 1990, Let's Take the Con Out of Econometrics, *American Economics Review*, **73** (March 1983), 31-43.

# GIGO (Garbage In, Garbage Out) Science – or pseudo-science – “where uncertainties in inputs must be suppressed lest outputs become indeterminate”

From: Uncertainty and Quality in Science for Policy
by Silvio Funtowicz and Jerry Ravetz, Springer 1990.

# Models are fragile…

… And still some are surprised


PNAS RESEARCH ARTICLE | SOCIAL SCIENCES OPEN

**Observing many researchers using the same data and hypothesis reveals a hidden universe of uncertainty**

Edited by Douglas Massey, Princeton University, Princeton, NJ; received March 6, 2022; accepted August 22, 2022

"Will different researchers [73 teams] converge on similar findings when analyzing the same data?

…teams' results varied greatly, ranging from large negative to large positive effects"
(Massey et al. 2022)

# Global sensitivity analysis unveils the hidden universe of uncertainty in multiverse studies

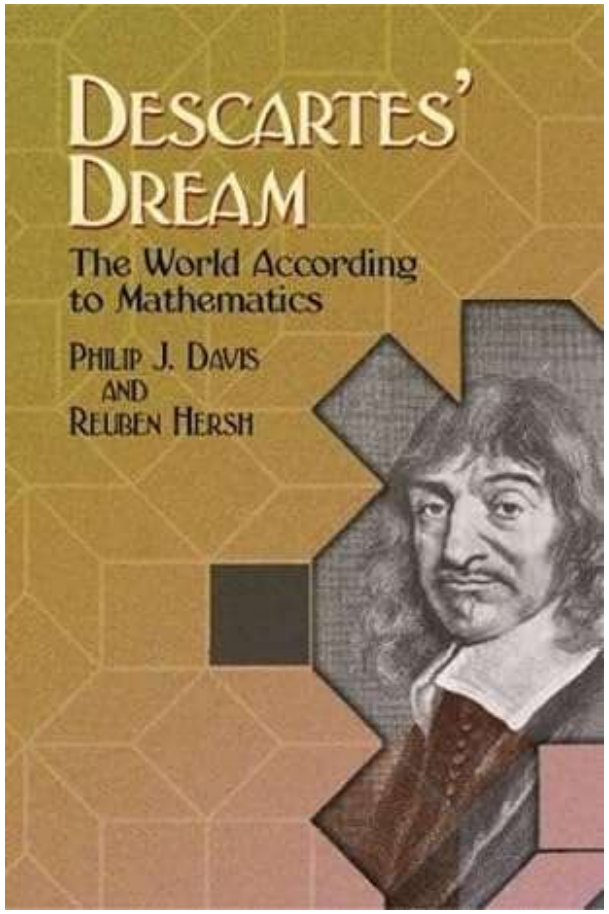
**AUTHORS**
Andrea Saltelli, Arnald Puy, Alessio Lachi, and Nate Breznau

# Gross asymmetry developers/ users

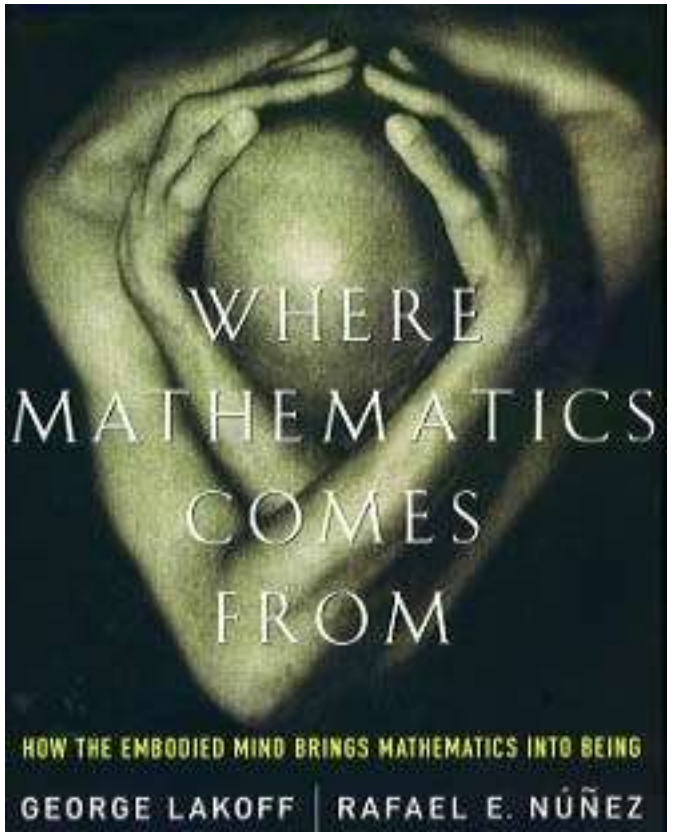
Models operate in a context of asymmetry of knowledge between developers and users (Jakeman *et al.*, 2006). There are 'black boxes' also in other families of quantification, typically algorithms or statistics. Yet this asymmetry may be larger for mathematical models.


Jakeman, A.J., R.A. Letcher, and J.P. Norton. 2006. 'Ten Iterative Steps in Development and Evaluation of Environmental Models'. Environmental Modelling & Software 21 (5): 602–14.

# Models are not written in the language of God

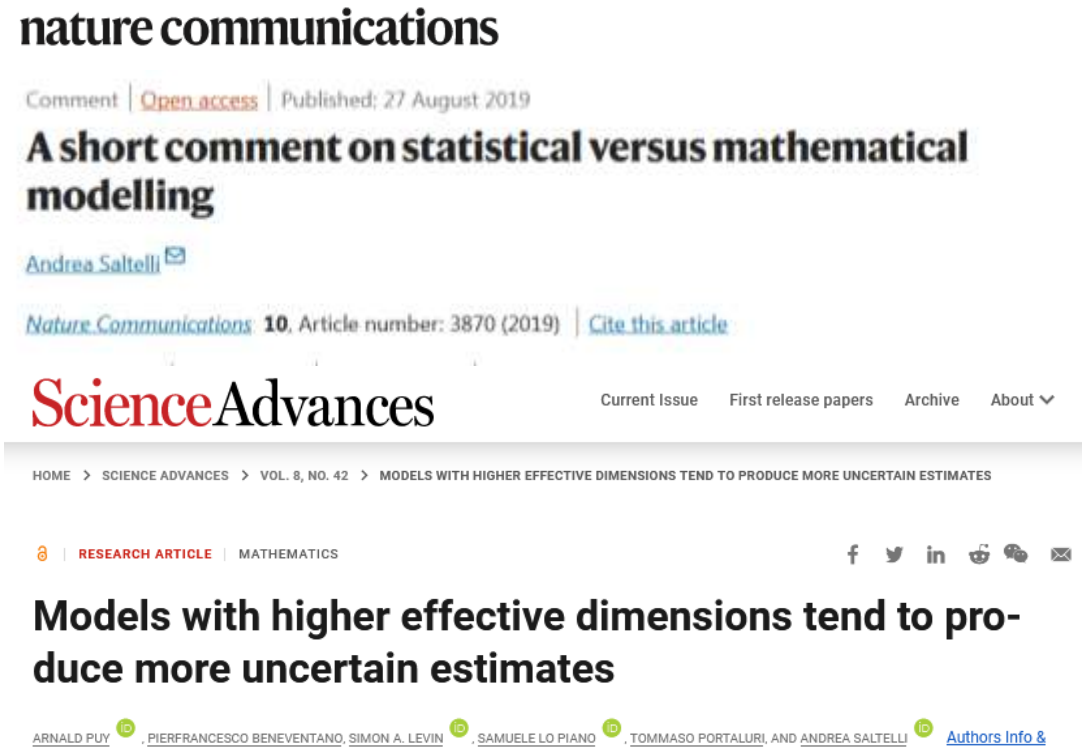


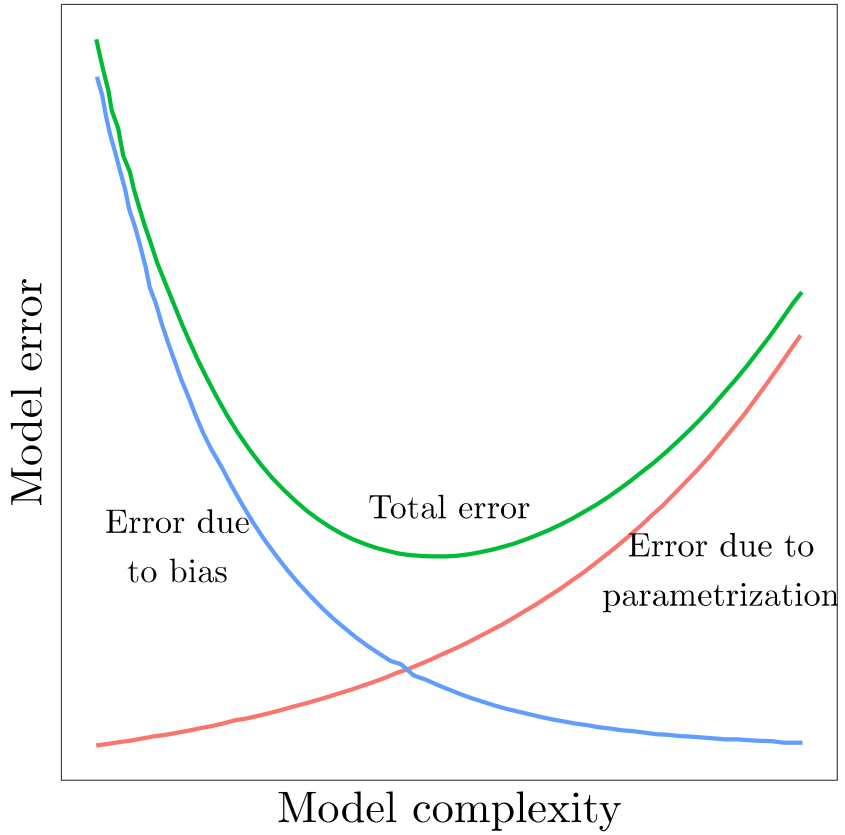

Models dispose of a unique repertoire of methods. Are endowed with unparallel epistemic authority that originates from mathematics, the highest ranked among scientific disciplines (Davies & Hersh, 1986), considered by the fathers of the scientific revolution the language of God himself, up to the point that reconnecting it to human experience is up today an unfinished project (Lakoff & Núñez, 2001).



# Models are vulnerable to modelling hubris

The conjecture of  O'Neill (1971), see also Turner & Gardner (2015), posits that too simple a model may miss important features of the system, and thus lead to systematic error, while a too complex one – burdened by an excessive number of estimated parameters, may lead to a greater imprecision due the error propagation.



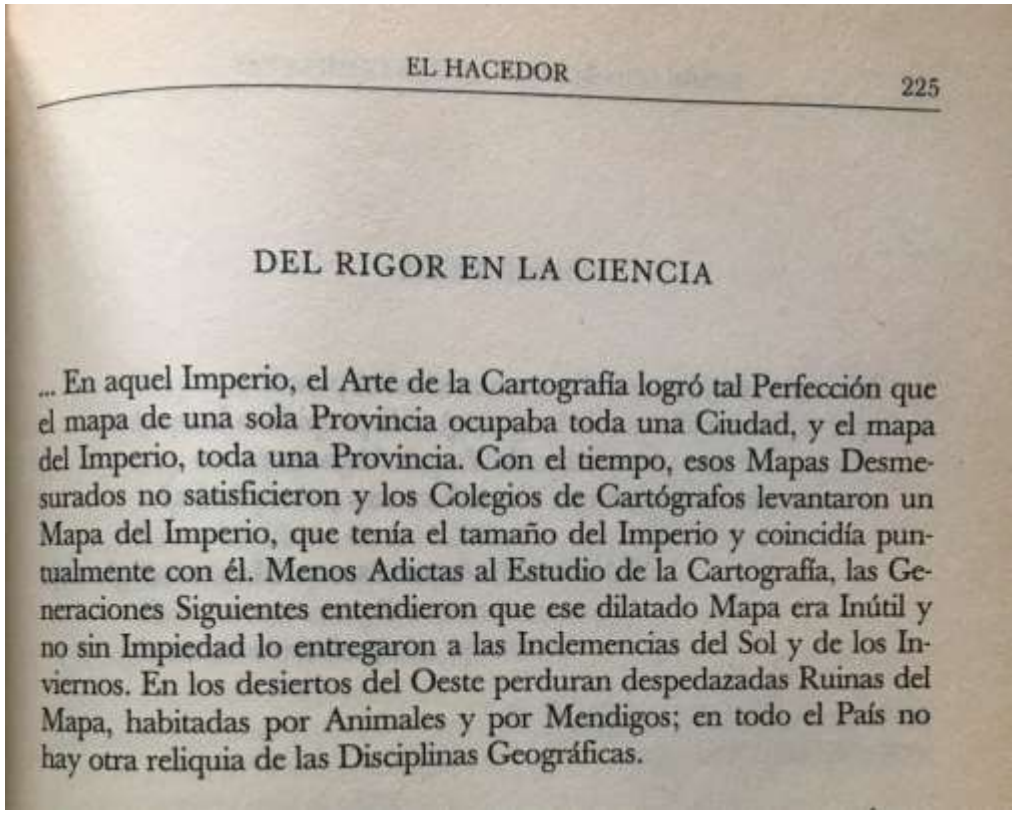




O'Neill, R. V. 1971. 'Error Analysis of Ecological Models'. In Radionuclides in Ecosystems, Proceedings of the Third National Symposium in Radioecology, edited by D. J. Nelson, 898–907. Oak Ridge - Tenn.

Turner, Monica G., and Robert H. Gardner. 2015. 'Introduction to Models'. In Landscape Ecology in Theory and Practice, 63–95. New York, NY: Springer New York.

# When too much is too much

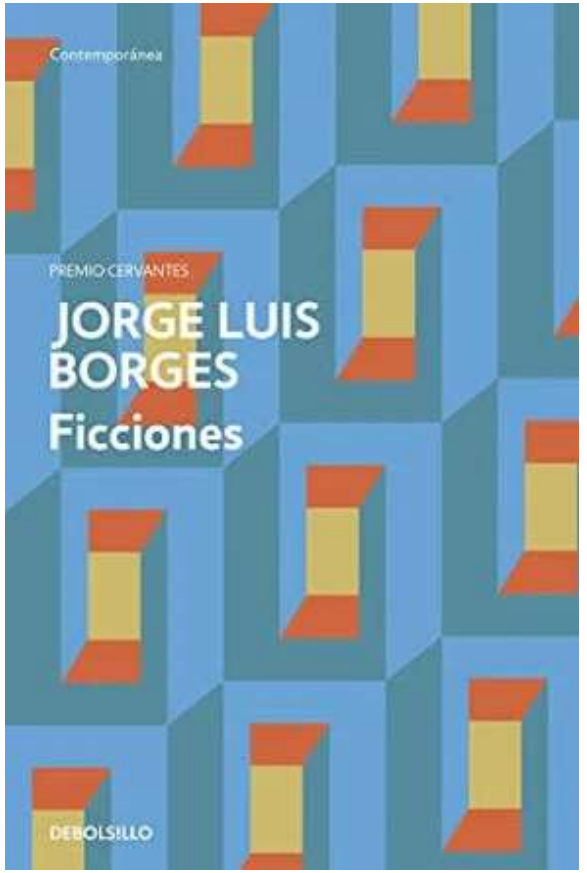
## Model as Jorge Luis Borges' (1946) one-to-one map of the empire



EL HACEDOR 225

DEL RIGOR EN LA CIENCIA

... En aquel Imperio, el Arte de la Cartografía logró tal Perfección que el mapa de una sola Provincia ocupaba toda una Ciudad, y el mapa del Imperio, toda una Provincia. Con el tiempo, esos Mapas Desmesurados no satisficieron y los Colegios de Cartógrafos levantaron un Mapa del Imperio, que tenía el tamaño del Imperio y coincidía puntualmente con él. Menos Adictas al Estudio de la Cartografía, las Generaciones Siguientes entendieron que ese dilatado Mapa era Inútil y no sin Impiedad lo entregaron a las Inclemencias del Sol y de los Inviernos. En los desiertos del Oeste perduran despedazadas Ruinas del Mapa, habitadas por Animales y por Mendigos; en todo el País no hay otra reliquia de las Disciplinas Geográficas.



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Royal Geographical Society with IBG

Perspective | Open Access

# Bring digital twins back to Earth

Andrea Saltelli, Gerd Gigerenzer, Mike Hulme, Konstantinos V. Katsikopoulos, Lieke A. Melsen, Glen P. Peters, Roger Pielke Jr, Simon Robertson ... See all authors

First published: 26 August 2024 | https://doi.org/10.1002/w

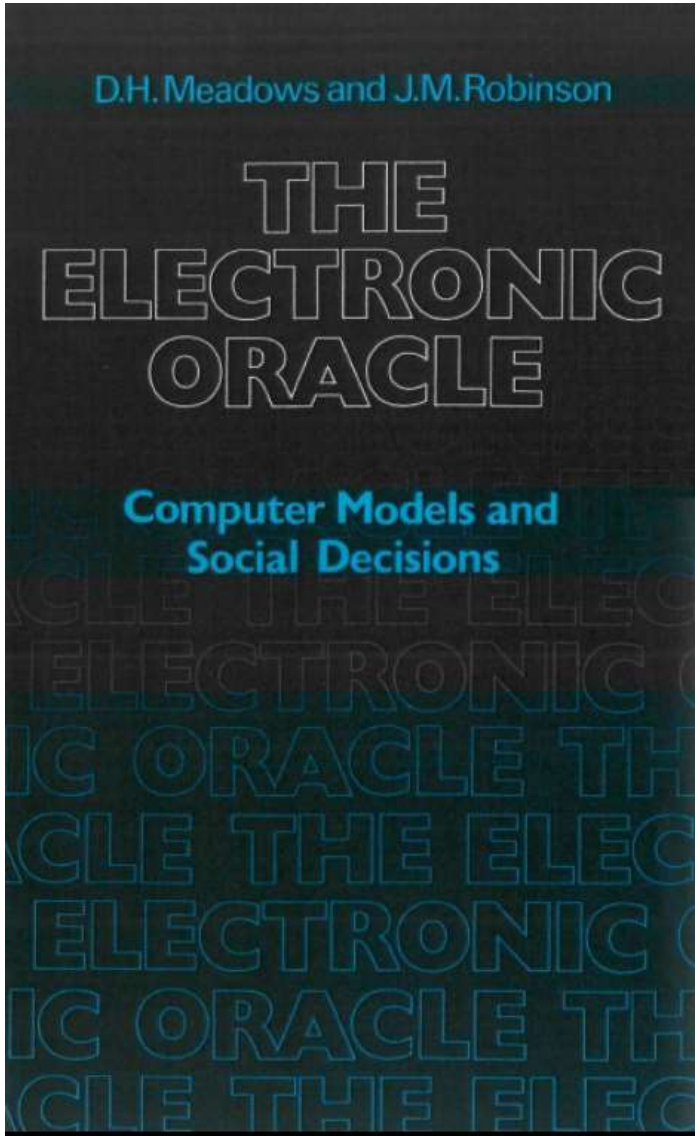
The Honest Broker

## Digital Twins of the Earth: Science or Pseudoscience?

A guest post by Andrea Saltelli

ROGER PIELKE JR.
SEP 09, 2024

Looking good!



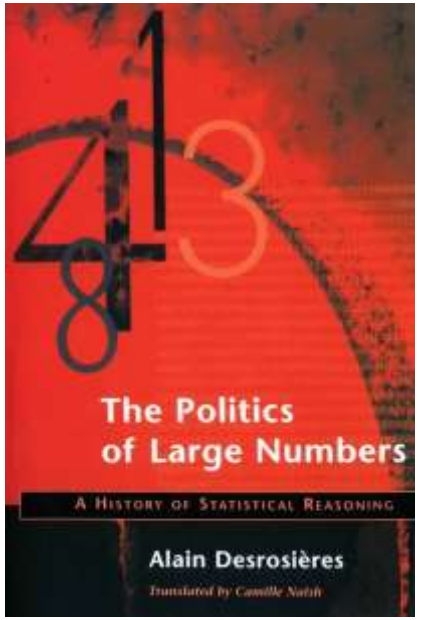

Meadows DH, Robinson JM. *The Electronic Oracle. Computer Models and Social Decisions*. John Wiley & Sons, Ltd; **1985.**

Donella Meadows

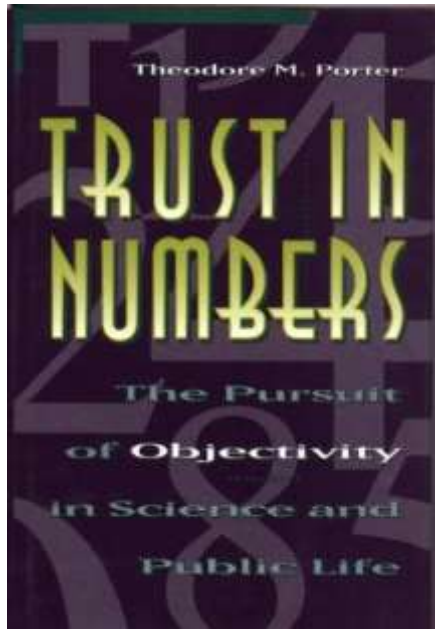
The list of complaints and suggestions for improvement from practitioners in the field has changed not at all over the years, and it is still true that virtually no one is following any of the suggestions.

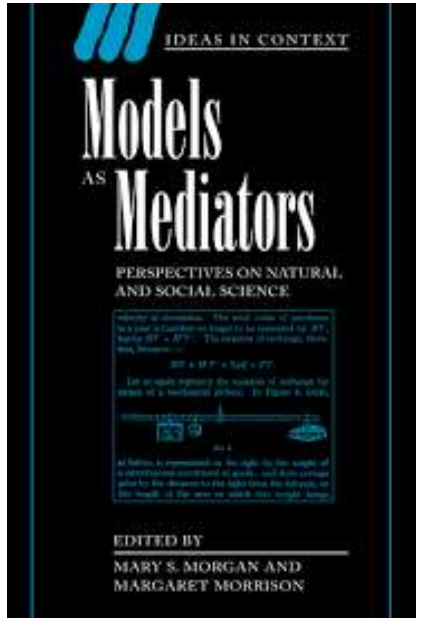
As far as I can tell, there are no exciting new methods, no more wisdom in matching method to problem, no more imagination in depicting society, and certainly no better standards of documentation. So the examples, literature references, and conclusions we cite here are, I believe, still representative. Adding more recent examples would neither contradict nor make more clear any of the points of the book.

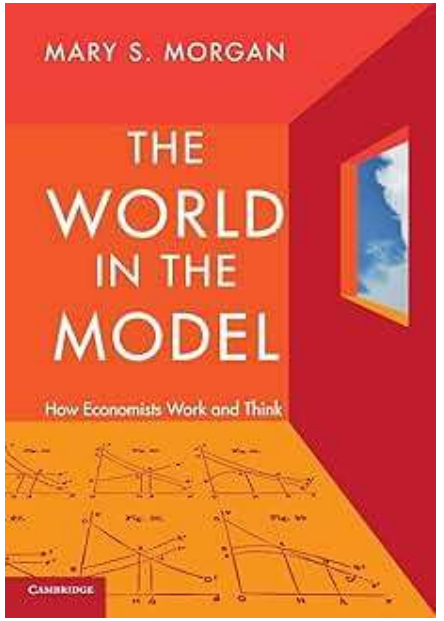
# Mathematical models escape sociology of quantification




Statistics has a much deeper connection to sociology, and to sociology of quantification in particular (Desrosières, 1998; Mennicken & Espeland, 2019; Mennicken & Salais, 2022) than mathematical modelling. Sociology of quantification treats impact assessment tools such as cost benefit analysis (Porter, 1995). Less on modelling, see exceptions: (Morgan, 2012, Morgan & Morrison, 1999).

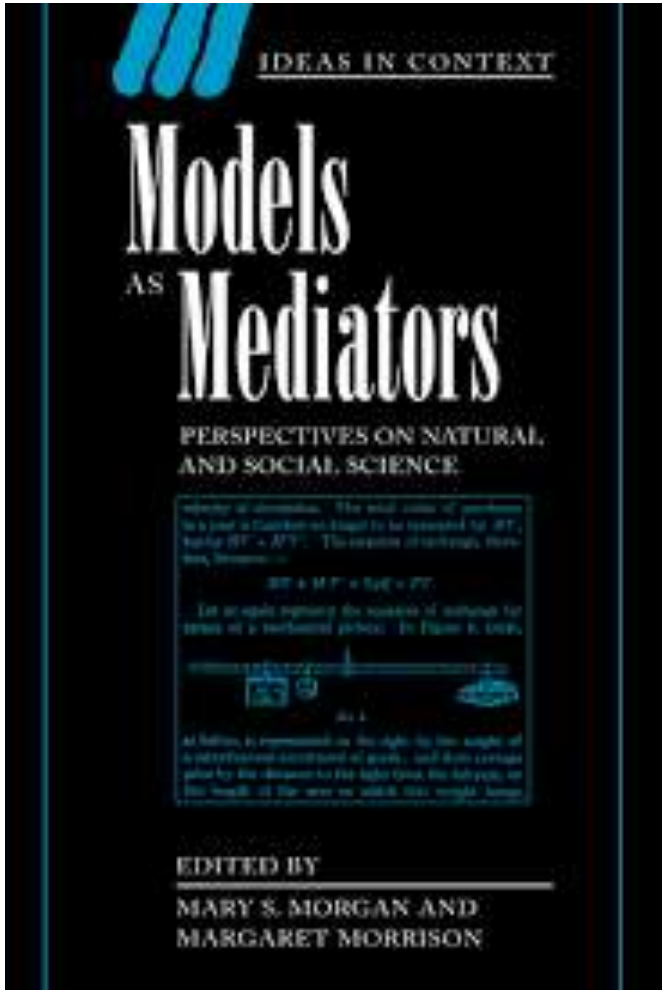


**Still we need models! As the most effective mediators between theory and reality**

Due to their independence from both theory and the world, models act as “mediators”, instruments that advance understanding thanks to the tacit craftsmanship of scientists (Morgan & Morrison 1999).



# Models' grip on policy

Models have their own political economy - economicism, solutionism, reductionism, transforming of the qualitative into quantitative (Stirling, 2023a, 2023b).

The percentage of non-reproducible studies in the field of clinical medical research could reach 85% (Chalmers and Glasziou, 2009). Nobody can provide a similar figure for mathematical modelling.

'Navigating the political' (van Beek *et al.* 2022)

Acting as chameleons, jumping across contexts, Pfleiderer (2020).

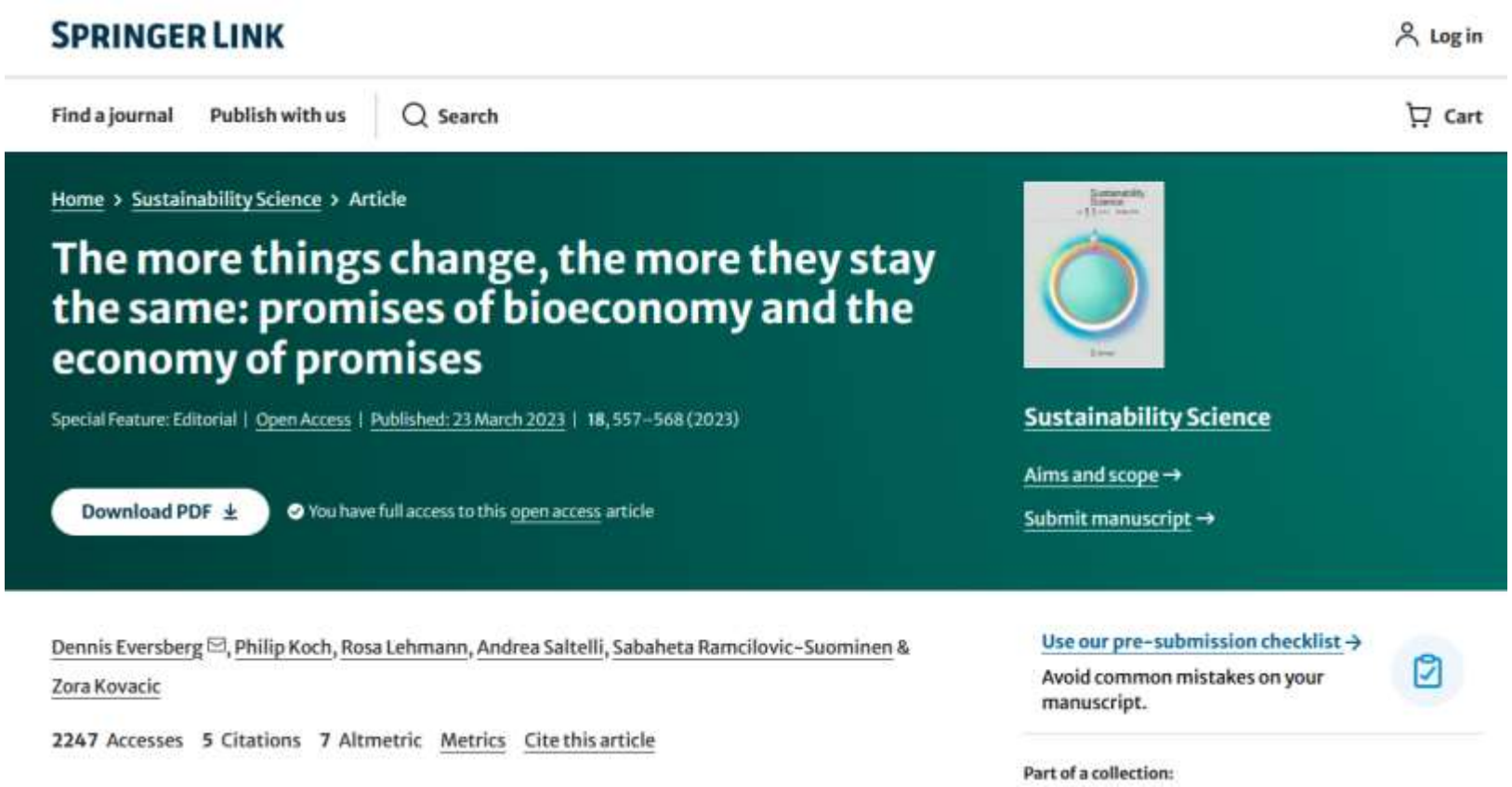
Source: National Geographic


Chalmers, Iain, and Paul Glasziou. 2009. 'Avoidable Waste in the Production and Reporting of Research Evidence'. The Lancet 374 (9683): 86–89.

Pfleiderer, Paul. 2020. 'Chameleons: The Misuse of Theoretical Models in Finance and Economics'. Economica 87 (345): 81–107.

Stirling, Andy. 2023. 'Against Misleading Technocratic Precision in Research Evaluation and Wider Policy – A Response to Franzoni and Stephan (2023), "Uncertainty and Risk-Taking in Science"'. Research Policy 52 (3): 104709.

van Beek, Lisette, Jeroen Oomen, Maarten Hajer, Peter Pelzer, and Detlef van Vuuren. 2022. 'Navigating the Political: An Analysis of Political Calibration of Integrated Assessment Modelling in Light of the 1.5 °C Goal'. Environmental Science & Policy 133 (July):193–202.



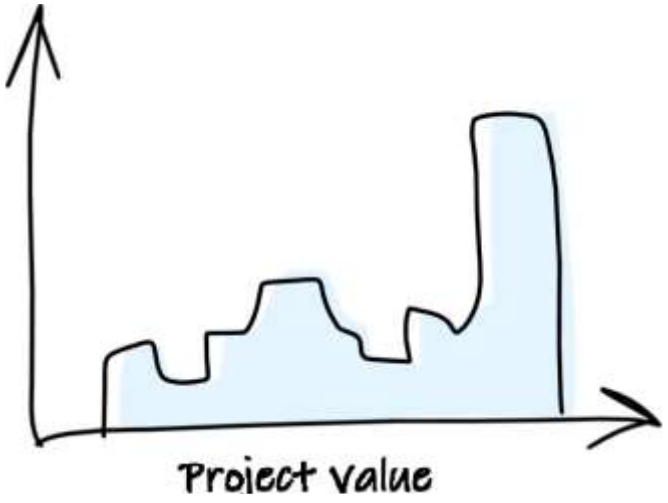

More critical work

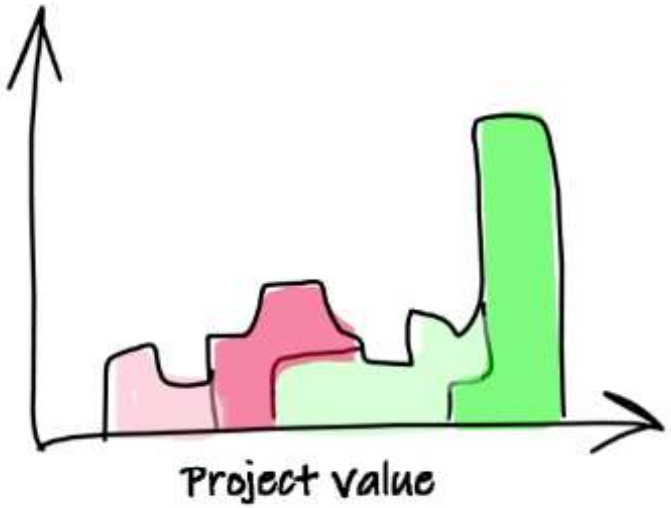
Debunking promises of circular economy, energy transitions, …

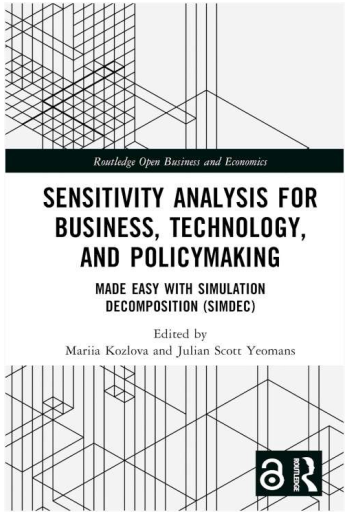
# Models for techno-promises

Economics of Techno-scientific Promises' (ETP)= The promise of 'transformation without transformation'

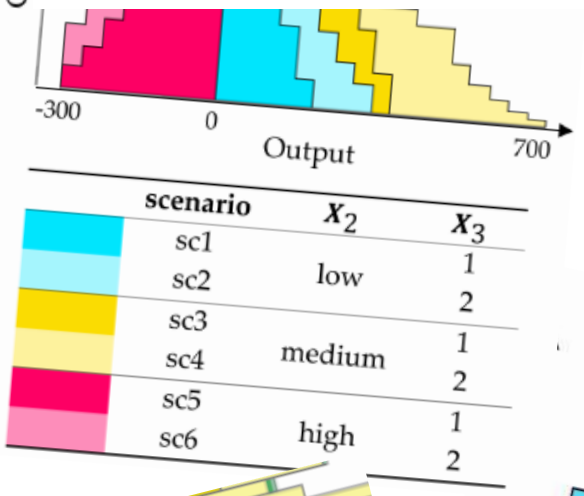
# Is there a solution to all this?
# Is there a way to make models simultaneously more interpretable, transparent, and democratic?



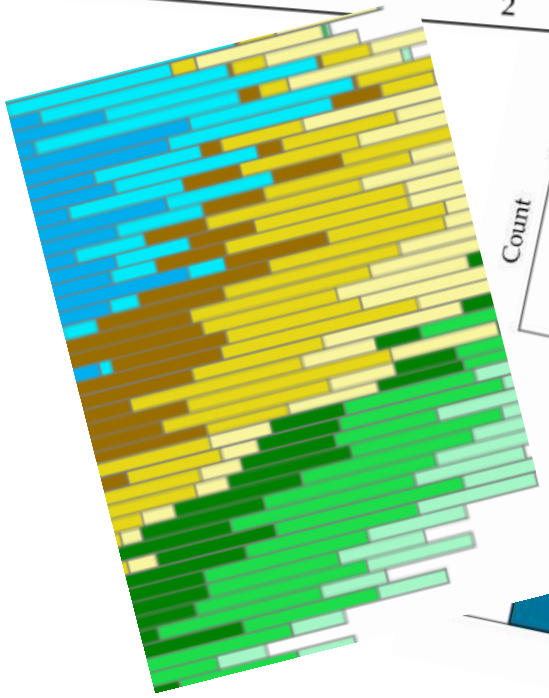



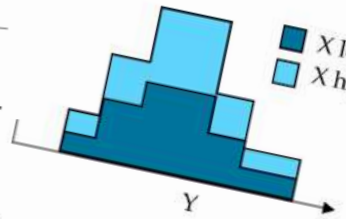



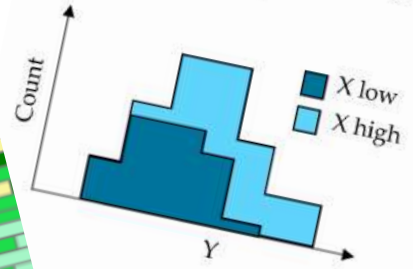
# It is the colours, stupid!

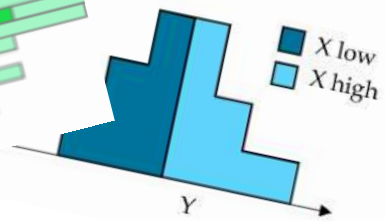


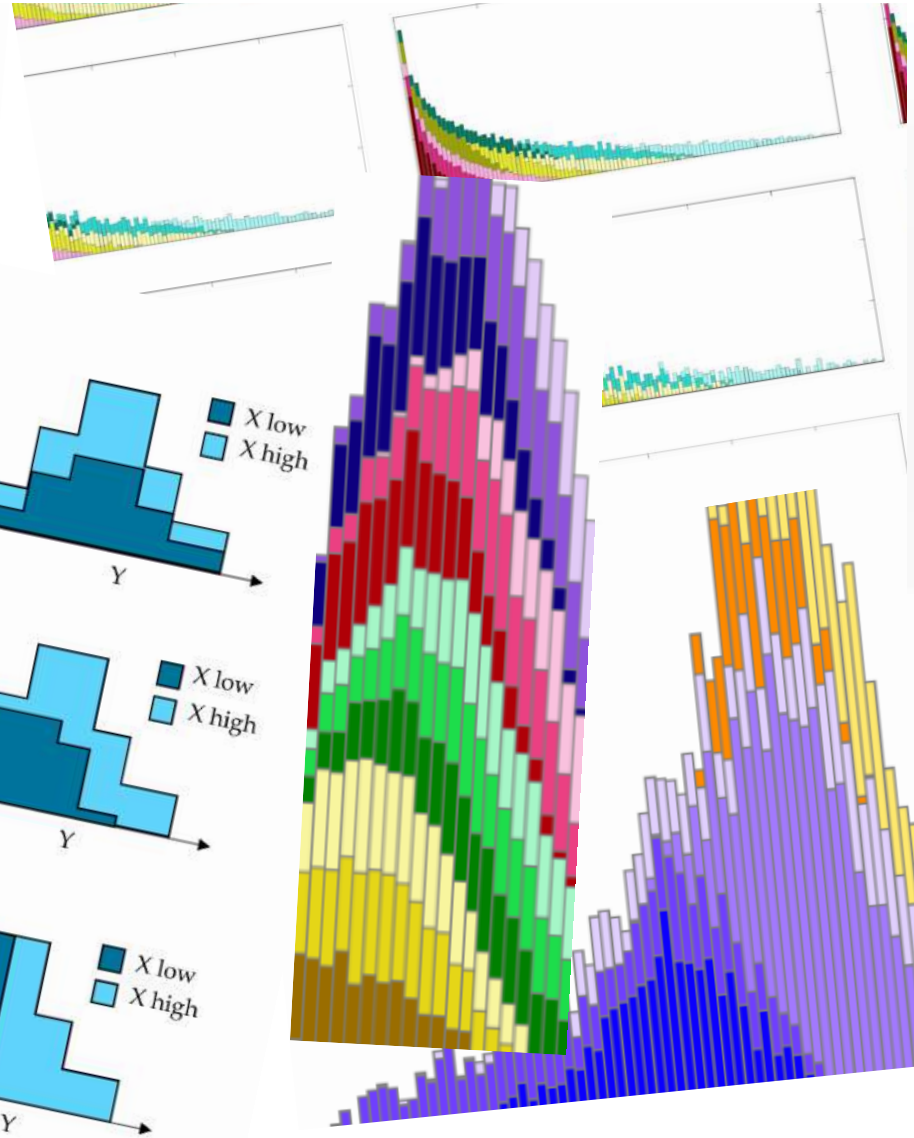

| | scenario | $X_2$ | $X_3$ |
|---|---|---|---|
| | sc1 | low | 1 |
| | sc2 | | 2 |
| | sc3 | medium | 1 |
| | sc4 | | 2 |
| | sc5 | high | 1 |
| | sc6 | | 2 |

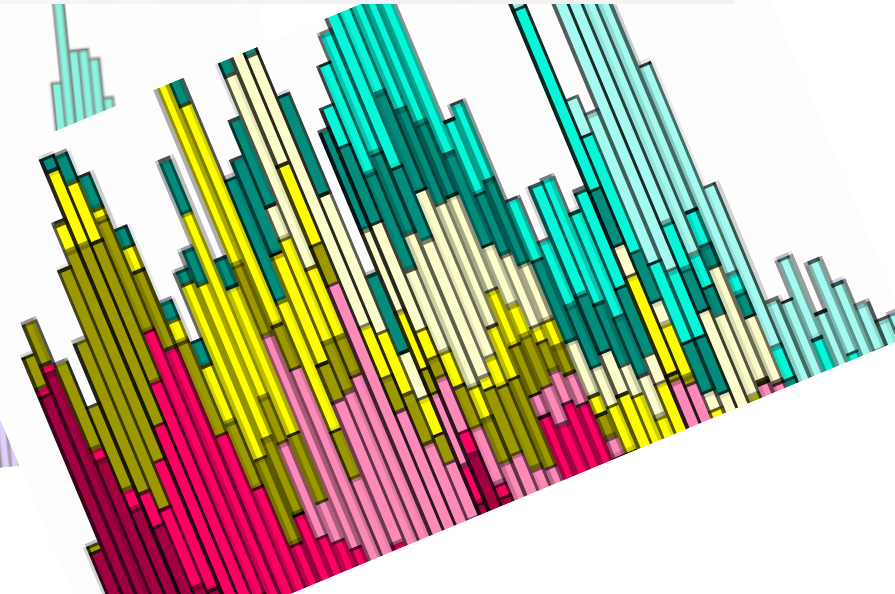






# Applications to business, engineering, environmental sciences, behavioural sciences …

Chapter 11 | 26 pages

Capturing multi-dimensional nonlinear behaviour of a steel structure reliability model – global sensitivity analysis

By Antti Ahola, Mariia Kozlova, Julian Scott Yeomans

Abstract

Chapter 12 | 46 pages

Sensitivity analysis of a superconducting magnet design model

By Manuel García Pérez, Mariia Kozlova, Susana Izquierdo Bermúdez, Juan Carlos Pérez, Julian Scott Yeomans

Abstract

Part V | 26 pages

Applications: Behavioural science

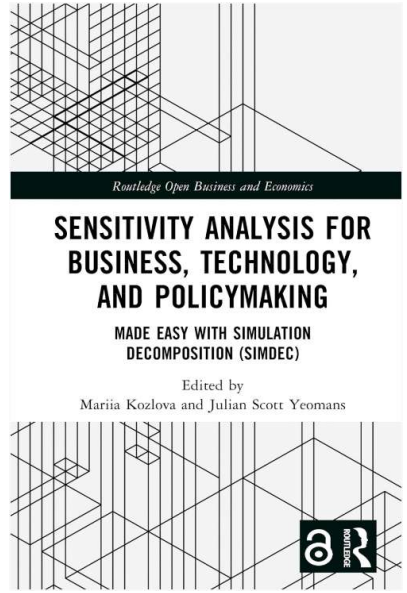
Chapter 13 | 24 pages

New level of personal decision-making

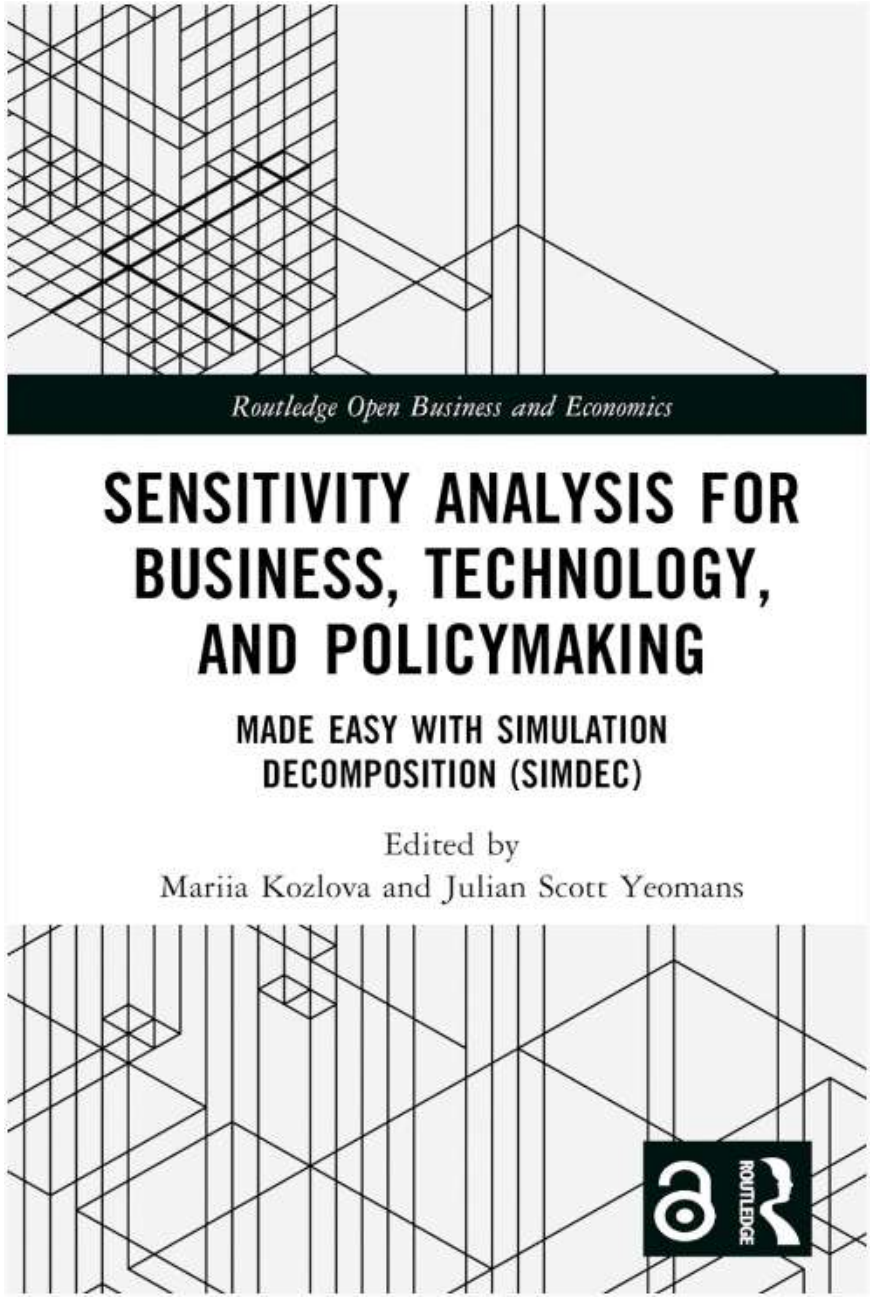
Day-to-day choices with SimDec

By Anna Sidorenko, Daria Moshkivska, Mariia Kozlova, Julian Scott Yeomans

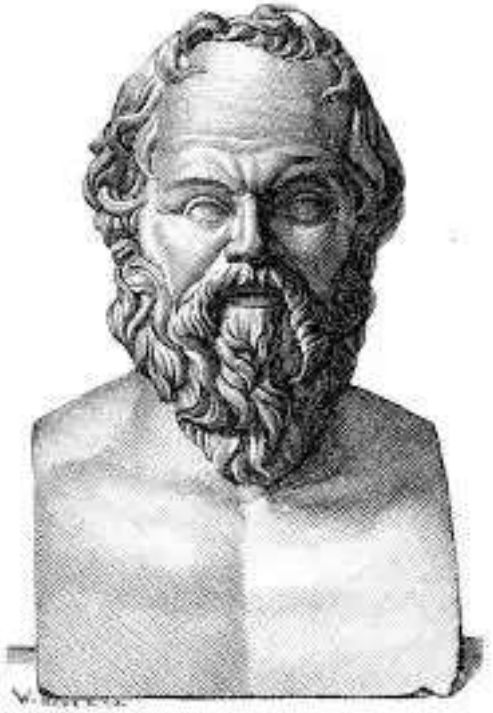
## Where next?



"Saying that this work democratizes mathematical modelling is perhaps a stretch too far. That it democratizes uncertainty and sensitivity analyses is a legitimate claim"



“An unexamined life is not worthy of living”



“How about an unexamined model?”

# END

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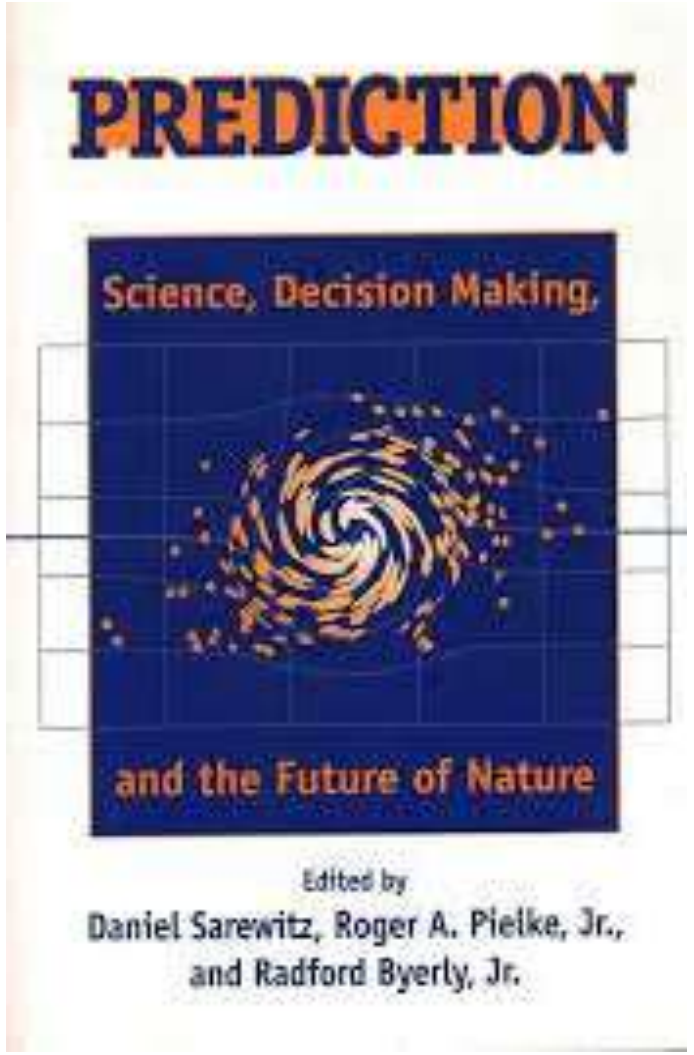
# Why models live in a state of exception

**Models cannot be falsified**

Models do not meet classic (Popperian) criteria of scientificity. Oreskes (2000) has observed that model-based predictions tend to be treated like logical inferences in a classic hypothetic-deductive model. The relation between models and data is often more symbiotic than adversarial. In climate studies this relation has been defined as 'incestuous', exactly to make the point that in modelling studies using data to prove a model wrong may not be straightforward (Edwards, 1999).




Edwards, P.N. 1999. 'Global Climate Science, Uncertainty and Politics: Data-laden Models, Model-filtered Data'. Science as Culture 8 (4): 437–72.

# Consequences descending from state of exception

## Ritual use

An analogy between statistical and mathematical modelling is in the 'ritual' use of methods. Rituals in statistics are described in Gigerenzer (Gigerenzer, 2018; Gigerenzer & Marewski, 2015). For models here an anecdote by Kenneth Arrow: producing one month-ahead weather forecasts

*"... The commanding general is well aware that the forecasts are no good. However, he needs them for planning purposes"*

See also Niklas Luhmann 'deparadoxification' (Moeller, 2006); See also politicians' claim: 'We follow the science' during COVID-19

Gigerenzer, Gerd. 2018. 'Statistical Rituals: The Replication Delusion and How We Got There'. Advances in Methods and Practices in Psychological Science 1 (2): 198–218.

# Consequences descending from state of exception

## Models and trans-science

Models lend themselves to trans-science (Weinberg, 1972).

- How many people will sit in autonomous cars by 2050
- How will the spread of malaria change if global temperature increases by 1.5ºC
- What will be the cost of CO2 averaged over the next three centuries

Weinberg, AM. 1972. ‘Science and Trans-Science’. *Minerva* 10:209–22.

# Conclusions

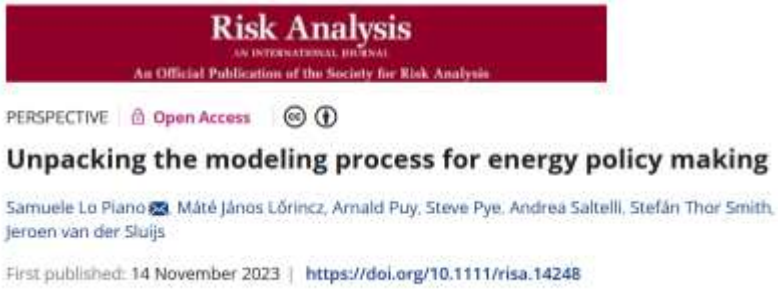

"models are more symbolic vehicles for gaining authority than objective technical framework" (1984)

The same way Digital Twins of the planet are 'scientifically prescribed' today …

Brian Wynne (and others such as William Keepin) debunked in the early 80's a totally off-the-mark model-based energy future, declared as 'scientifically prescribed' by analysts at IIASA …

A fast breeder reactor in the Netherlands, today an amusement park

See a summary here



# Why models live in a state of exception

**Models as the most effective mediators between theory and reality**

Models are metaphors that express “in an indirect form our presuppositions about the problem and its possible solutions”, and can thus assist in an **extended community of peers** to deliberate about social or ecological problems (Ravetz 2023).

Extended peer community

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From Wikipedia, the free encyclopedia

The concept of **Extended peer community** belongs to the field of Sociology of science, and in particular the use of science in the solution of social, political or ecological problems. It was first introduced by in the 1990s by Silvio Funtowicz and Jerome R. Ravetz.[1] in the context of what would become Post-normal science. An **Extended peer community** is intended by these authors as a space where both credentialed experts from different disciplines and lay stakeholders can discuss and deliberate.

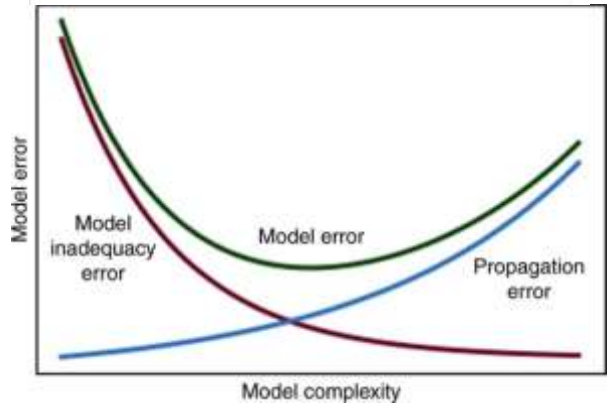
Solutions to resolve the state of exception

# Modelling of the modelling process (Sensitivity analysis, sensitivity auditing for de- and re-construction, on the example of statactivism)

➔ retrace what was assumed

➔ check the level of complexity

…

# ➔Avoid “quantifying at all costs”, expose ‘funny numbers’


Culture Unbound
*Journal of Current Cultural Research*

**Funny Numbers**

By Theodore M. Porter

# Solutions to resolve the state of exception

**Complexity of interpretation rather than complexity of construction**

The  I=PAT model, whereby the human impact on the environment is driven by population (P) times affluence (A) and technology (T). In the seventies, this model allowed a debate on the limit of growth that continues to the present day (Ehrlich & Holdren, 1971).

**Impact of Population Growth:** Complacency concerning this component of man's predicament is unjustified and counterproductive

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## Reciprocal domestication between models and society

The COVID pandemic of 2020 has dramatically increased the visibility of mathematical modelling, accompanied by a considerable level of controversy, either for the deficiencies of the model, or because of disagreement about the policies (Pielke, 2020; Rhodes & Lancaster, 2020). From ‘Flattening the curve’ to … distrust?

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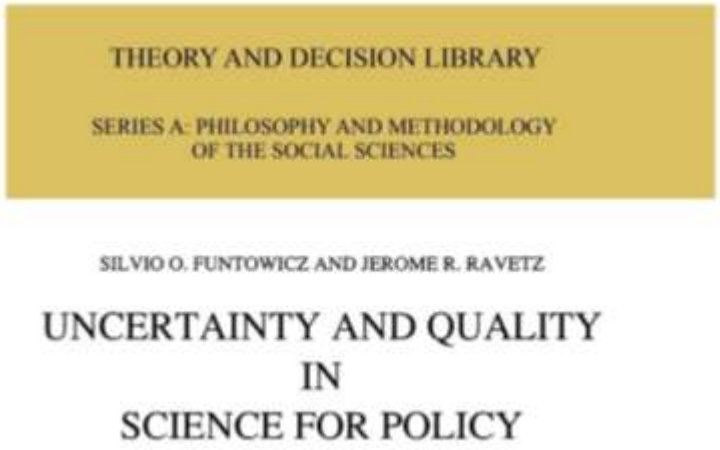
"COVID-19 policies allocated sacrifice, privation and suffering across all walks of society [but] radically different responses from nation to nation—from draconian lockdowns, to relatively permissive and flexible pandemic regimes—made obvious to all that the value of scientific evidence was to support what was politically desirable and possible in different contexts

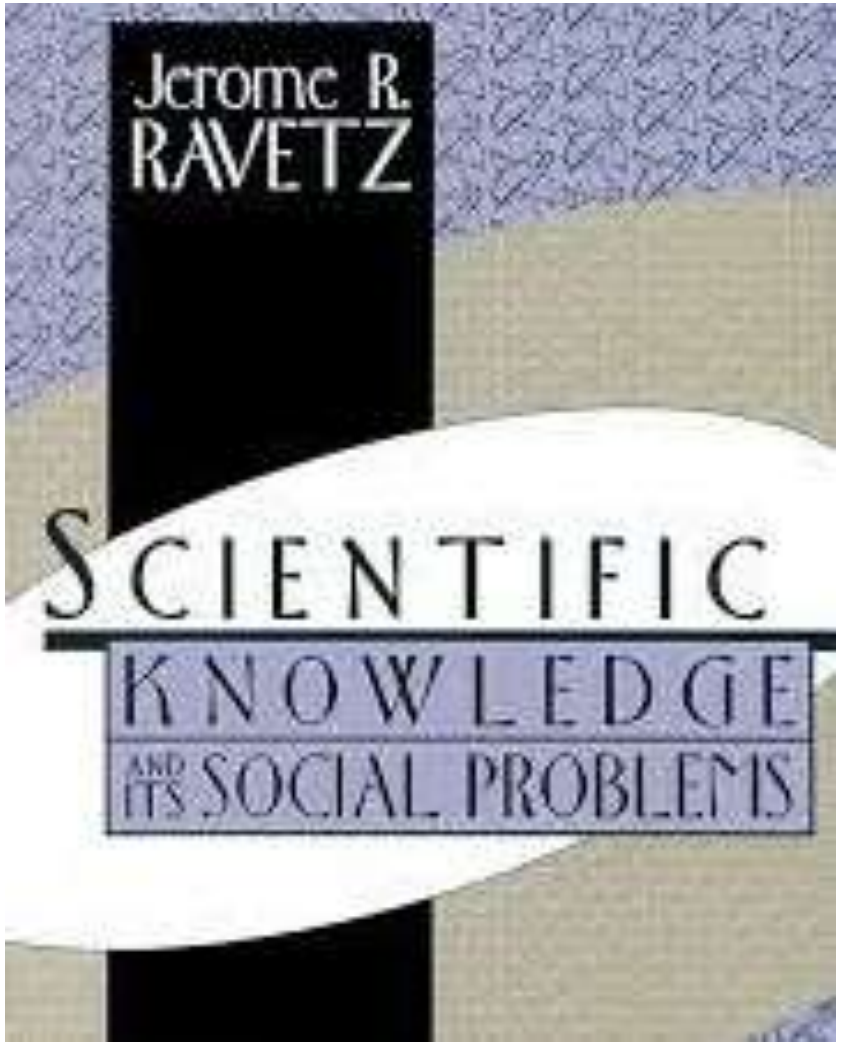
Mostly provided by models

# Solutions to resolve the state of exception

**Defog the mathematics of uncertainty**

An important issue in mathematical modelling is the management of uncertainty. Uncertainty quantification at the heart of the scientific method, and *a fortiori* in the use of science for policy.



# Solutions to resolve the state of exception: adopt more lenses

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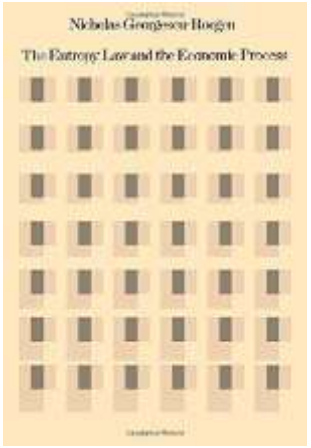
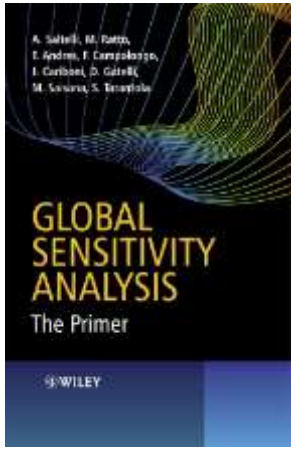
# Proposed lenses

- Non-Ricardian economics
- Bioeconomics (in the sense of Nicholas Georgescu-Roegen)
- Approaches originated in the context of post-normal science
  - global uncertainty and sensitivity analysis
  - sensitivity auditing
  - NUSAP
  - quantitative storytelling







# Contrasting invisibilities

Non-Ricardian economics: invisibility of qualities, whereby all hours of work are taken to have the same value

Bioeconomics: invisibility of nature, whereby natural resources are considered as infinite or infinitely substitutable

Post-normal science: invisibility of values, obfuscated by the purported neutrality of quantification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