



BARCELONA
SCHOOL OF
MANAGEMENT



Uncertainty from different perspectives

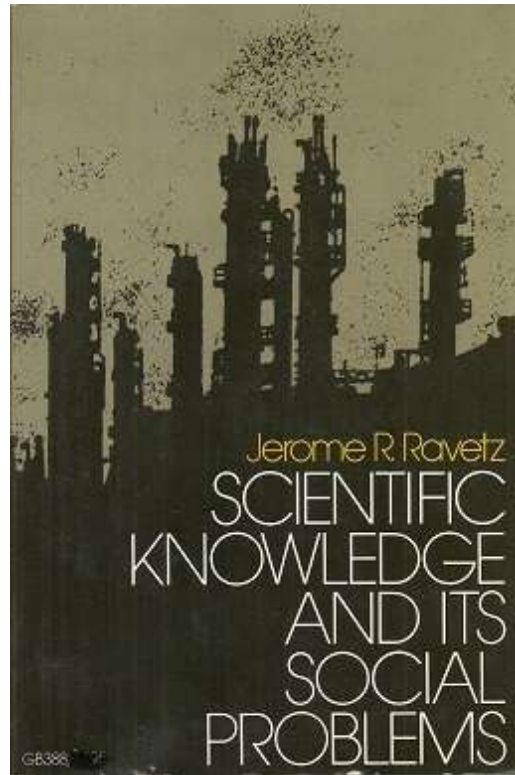
Andrea Saltelli

June 15, 2026, École d'été
PRISMA, Université de Genève

PART I — Uncertainty, risk, ignorance



Jerome R. Ravetz



1971



1990

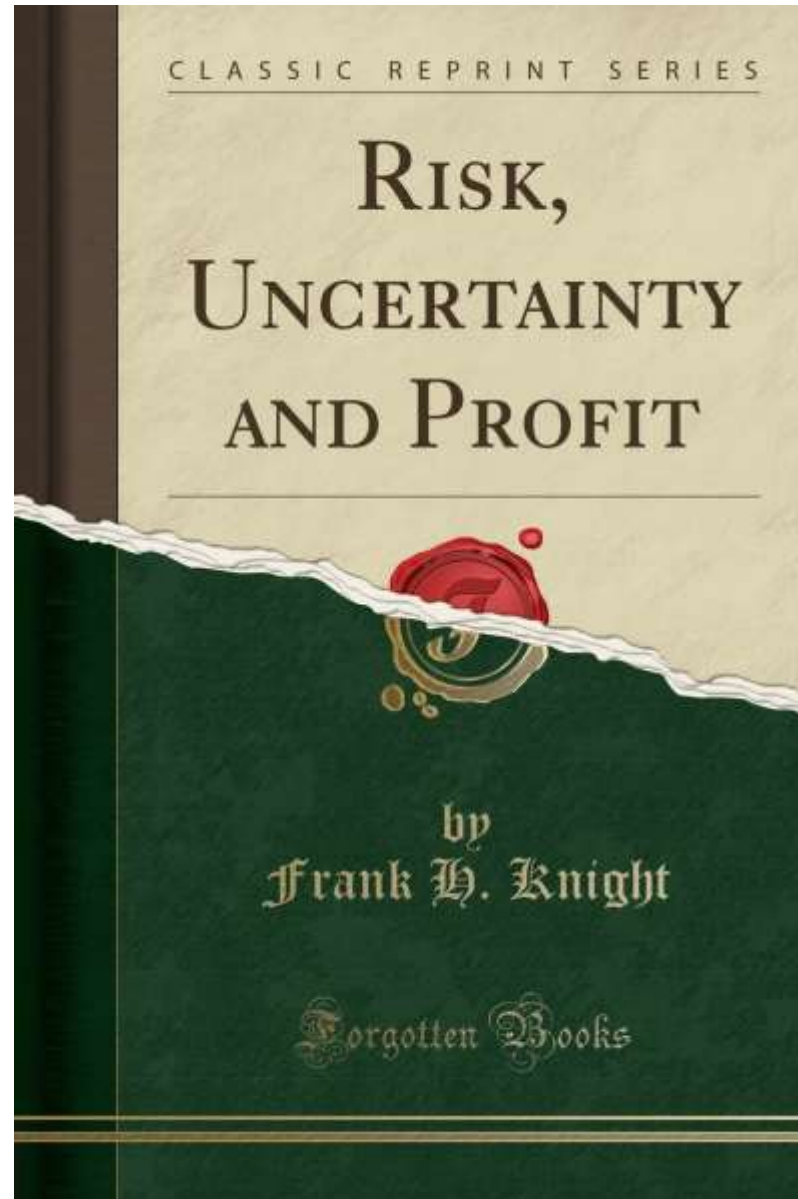
Partly based on Saltelli, Andrea, and Jerome R. Ravetz. 2023. 'Uncertainty, Risk and Ignorance'. In *Elgar Encyclopedia of Ecological Economics*. Edward Elgar Publishing. Available in our folder 'Literature'

Uncertainty is controversial both
across and within professions

Frank Knight (1921) distinguished risk from uncertainty

Risk = know outcomes & probabilities;
roulette game

Uncertainty = unsure about the probabilities;
starting a business



Frank H. Knight
1885-1972

But the story has many twists

The debate between Bruno De Finetti (later also Frank Ramsey) on one side and John Maynard Keynes and Frank Knight on the other: **a fundamental disagreements in decision theory**



Bruno De Finetti
(1906–1995)



Leonard Jimmie Savage
(1917–1971)



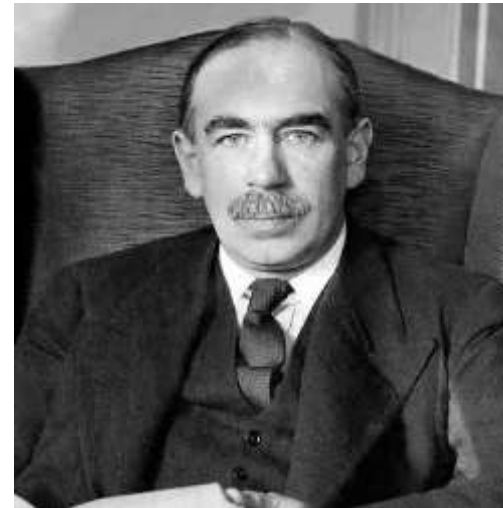
Frank Ramsey
(1903–1930)

But the story has many more twists

Savage and Ramsey: pioneers of subjective probability theory for rational decision-making – Keynes and Knight: sceptical that all uncertainties could be quantified probabilistically due to uncertainty & ambiguities

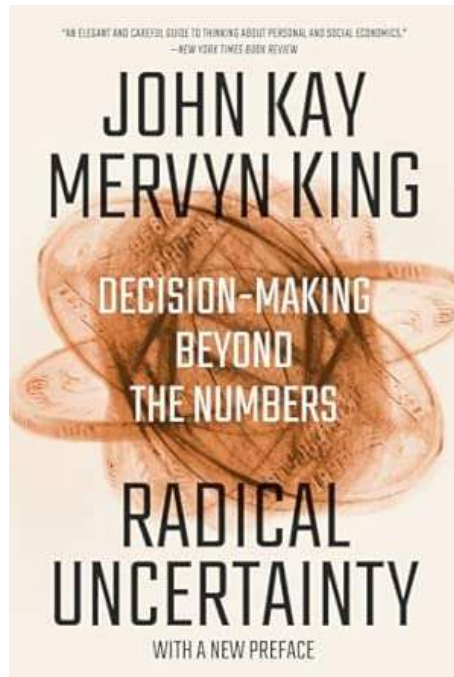


Frank H. Knight
1885–1972



John Maynard Keynes
1883–1946

Savage's agents are rational and indifferent to ambiguity. Keynes and Knight suggested that known risks are preferred over unknown ones → today, behavioural economics



FINANCIAL TIMES

US COMPANIES TECH MARKETS CLIMATE OPINION LEX WORK & CAREERS LIFE & ARTS HTSI

Opinion **Financial Times**

The other multiplier effect, or Keynes's view of probability

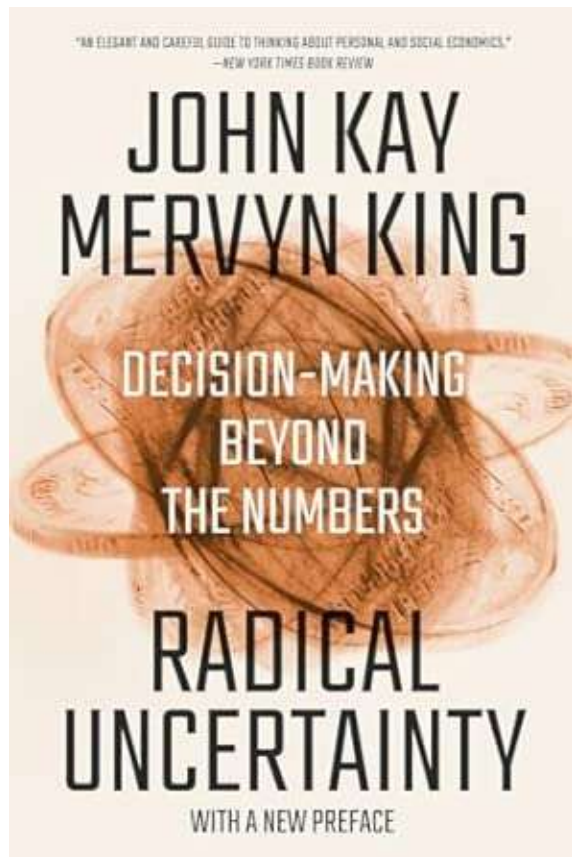
For the economist, probability was about believability, not frequency

JOHN KAY [+ Add to myFT](#)

A portrait of John Kay, an older man with grey hair and glasses, wearing a dark suit and a light blue shirt. He is looking directly at the camera with a slight smile.

But the story has many more twists

Some economists argue that Keynes was ‘convinced’ by the logic of Ramsey, while others disagree (Syll 2015) ...



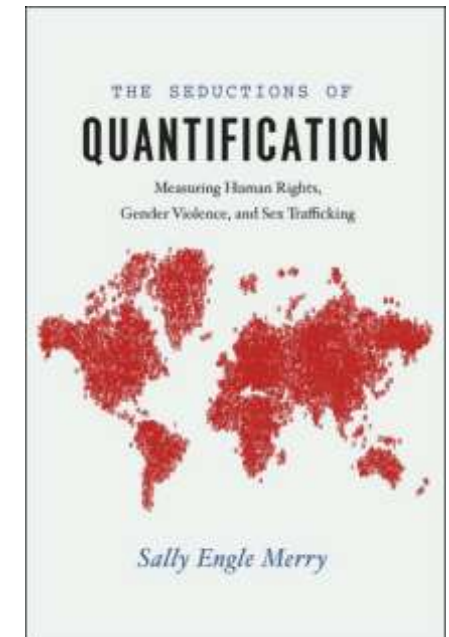
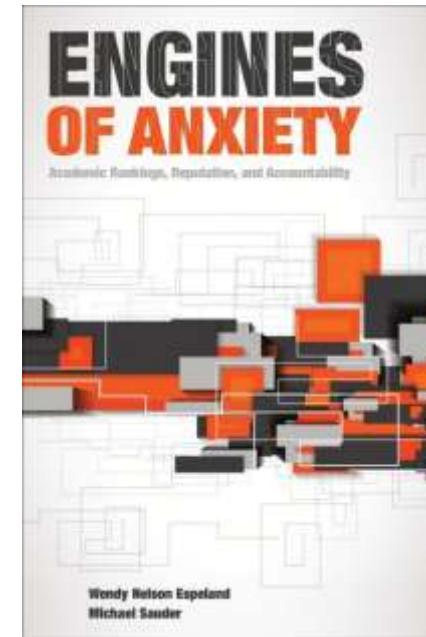
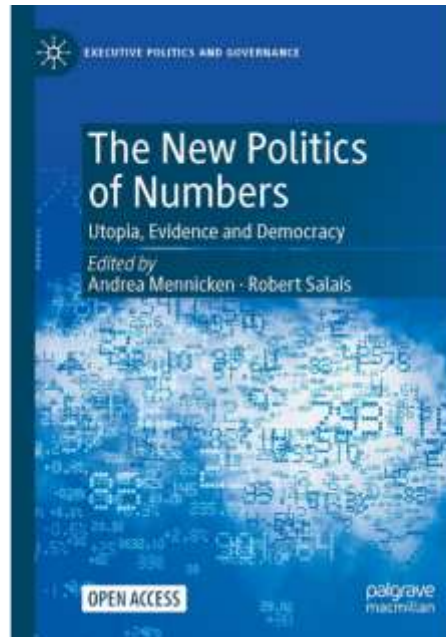
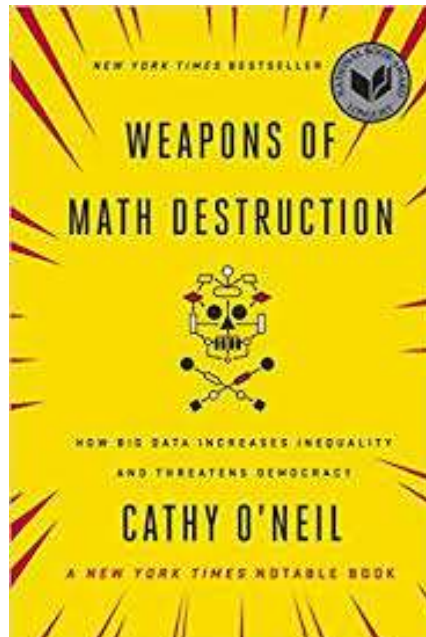
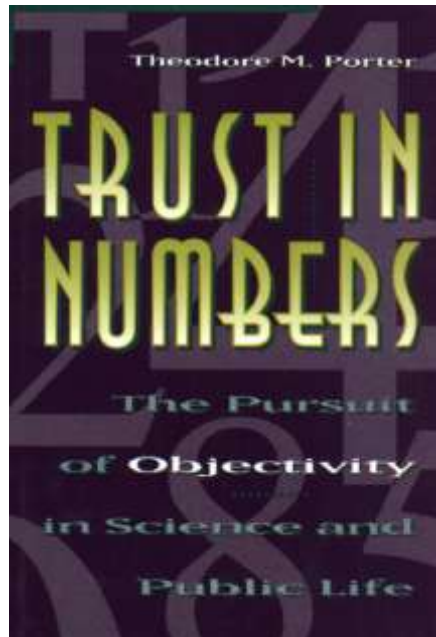
... yet quantification of uncertainty prevailed.

As noted by Kay & King (2020, p. 71), “The pressure to apply these methods outside their context was irresistible”

Lars P. Syll, 2015, The Keynes-Ramsey-Savage debate on probability. Retrieved from <https://larspsyll.wordpress.com/2015/07/22/the-keynes-ramsey-savage-debate-on-probability/>

The take of sociologists, ecologists, and scholar of
science and technology studies

The rhetoric of quantification is a recurring topic in sociology of quantification



Most analyses offered as input to policy are framed as cost-benefit analysis or risk analyses, but some environmentalists disagree ...

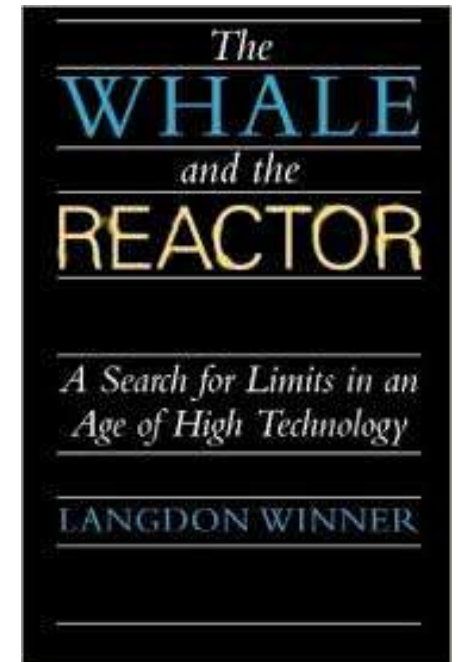
8

ON NOT HITTING
THE TAR-BABY

Winner, L., 1986. *The Whale and the Reactor: a Search for Limits in an Age of High Technology*. The University of Chicago Press, 1989 edition.



Langdon Winner



... citizens should be wary of falling into the trap of discussing the safety, e.g. of a new practice, product or installation, questioning instead why it was created and whose interest it serves



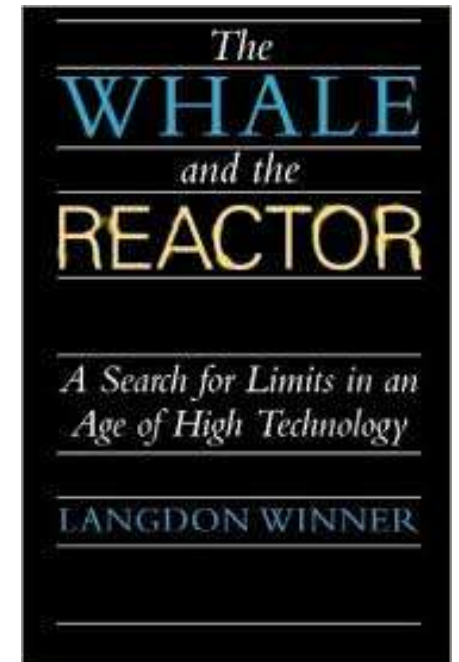
Langdon Winner

8

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THE TAR-BABY

Winner, L., 1986. *The Whale and the Reactor: a Search for Limits in an Age of High Technology*. The University of Chicago Press, 1989 edition.

Marris, C. 2001. Final Report of the PABE Research Project Funded by the Commission of European Communities, Contract Number: FAIR CT98-3844 (DG 12 - SSMI).



‘expected utility’, ‘decision theory’, ‘life cycle assessment’, ‘ecosystem services’ ‘sound scientific decisions’ and ‘evidence-based policy’ ... profusion of digits, promises of accuracy



Research Policy

Volume 52, Issue 3, April 2023, 104709



Discussion

Against misleading technocratic precision in research evaluation and wider policy – A response to Franzoni and Stephan (2023), ‘uncertainty and risk-taking in science’

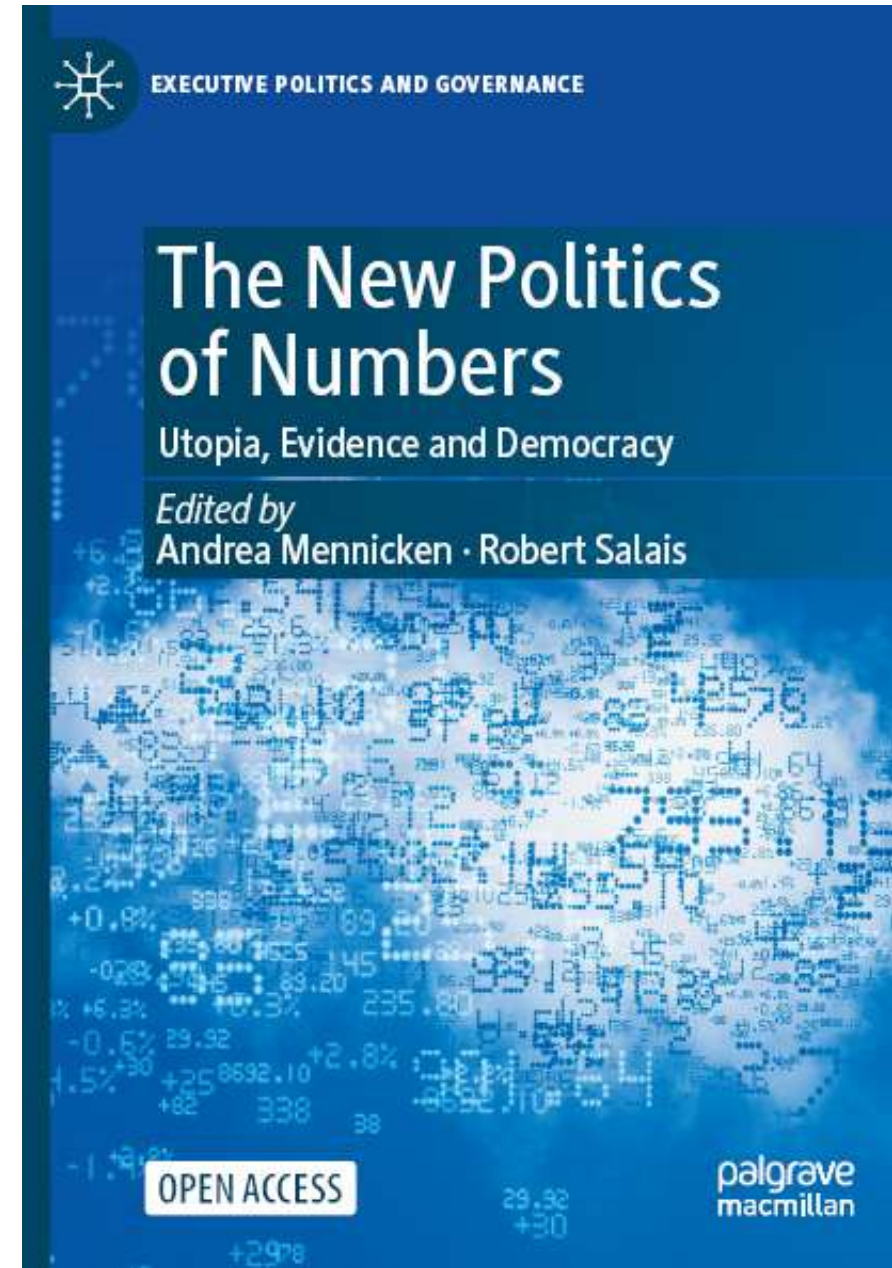
Andy Stirling ✉

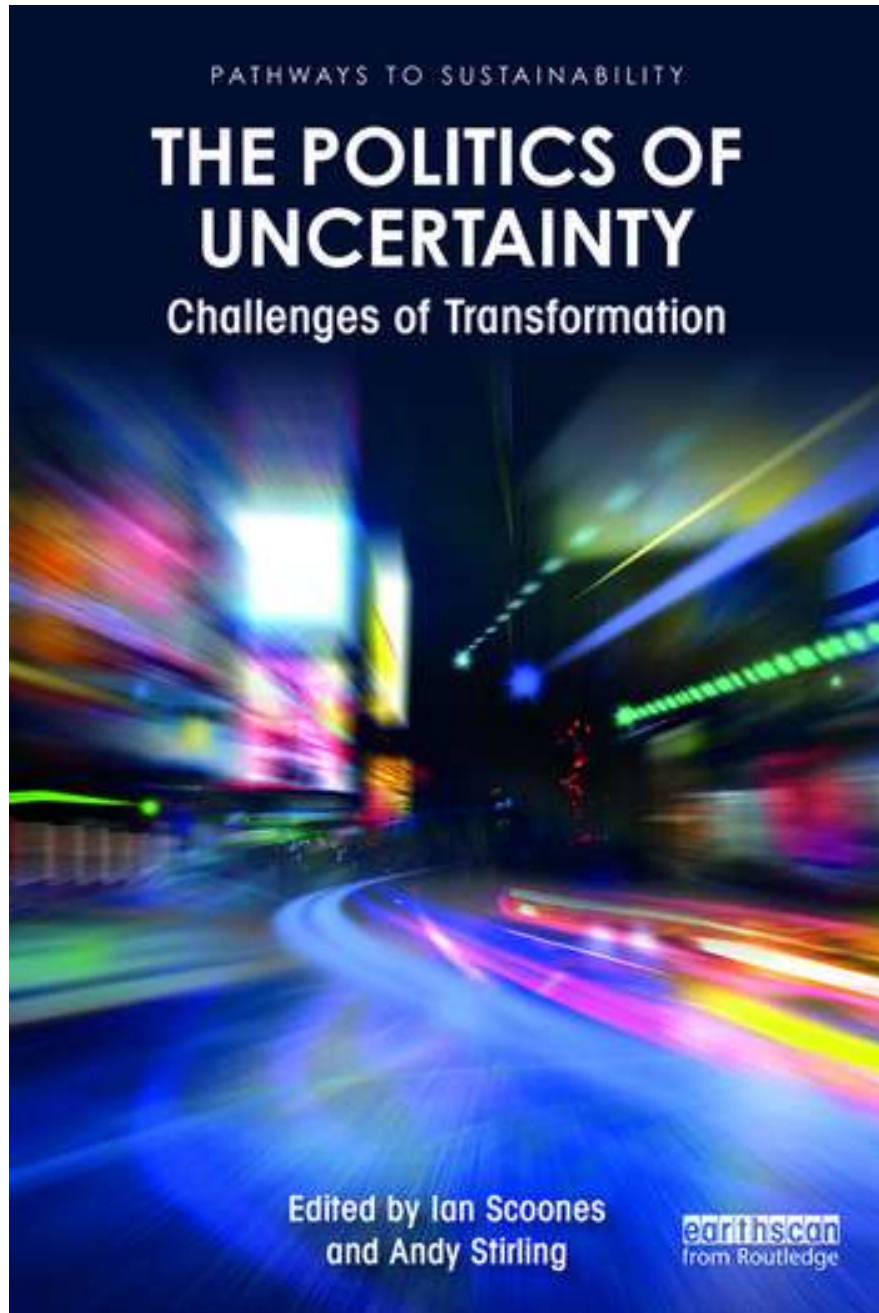


Andrew Stirling

Purported objectivity and neutrality, reductionism and justificationism contribute to a loss of democratic agency (a-democracy)

CHAPTER 12, “La donnée n’est pas un donné”: Statistics, Quantification and Democratic Choice, *Robert Salais*





“... embracing of uncertainties – as constructions of knowledge, materiality, experience, embodiment and practice – means challenging singular notions of modernity and progress as a hard-wired ‘one-track’ ‘race to the future’”

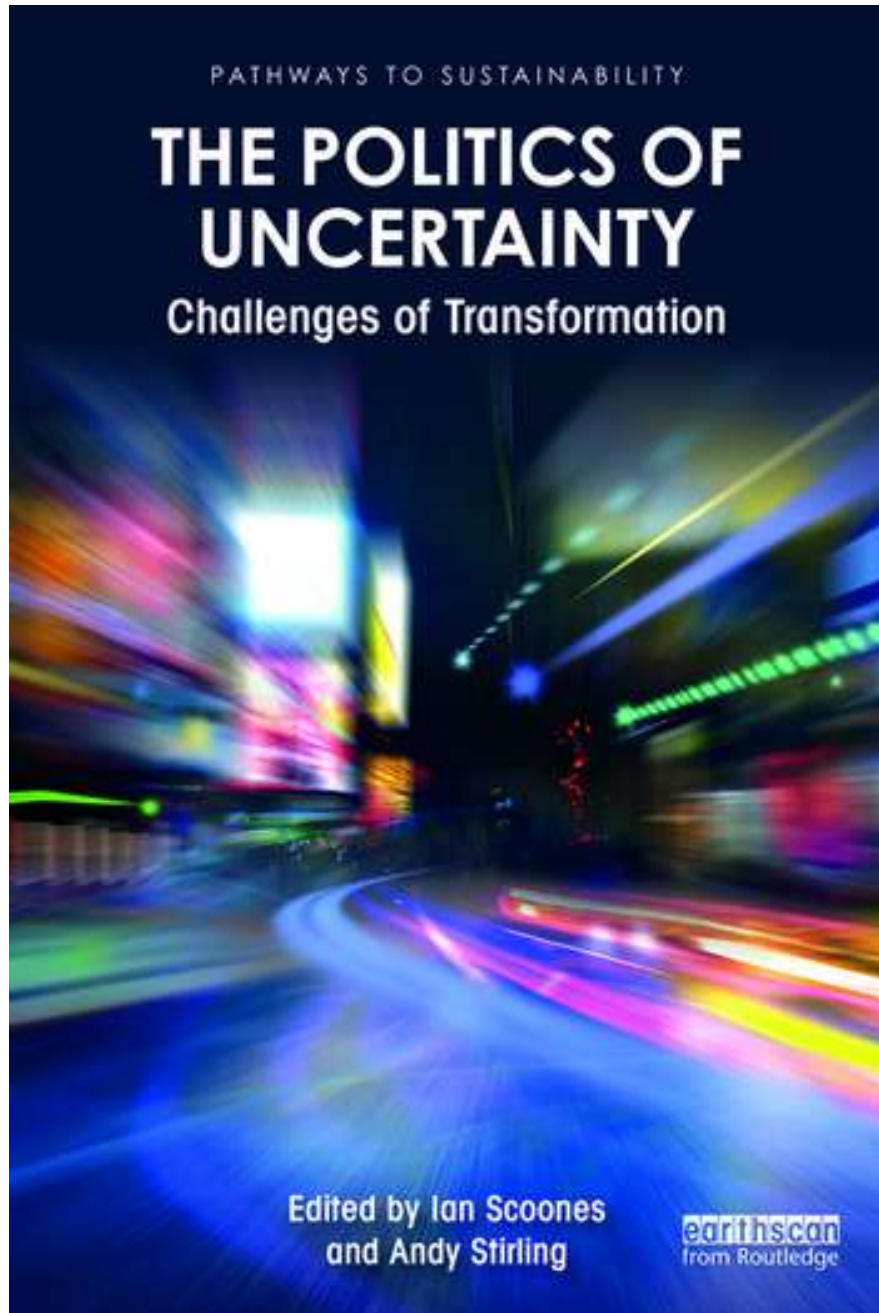
1

UNCERTAINTY AND THE POLITICS OF TRANSFORMATION

Ian Scoones and Andy Stirling

Open access:

<https://www.taylorfrancis.com/books/politics-uncertainty-ian-scoones-andy-stirling/e/10.4324/9781003023845>



3

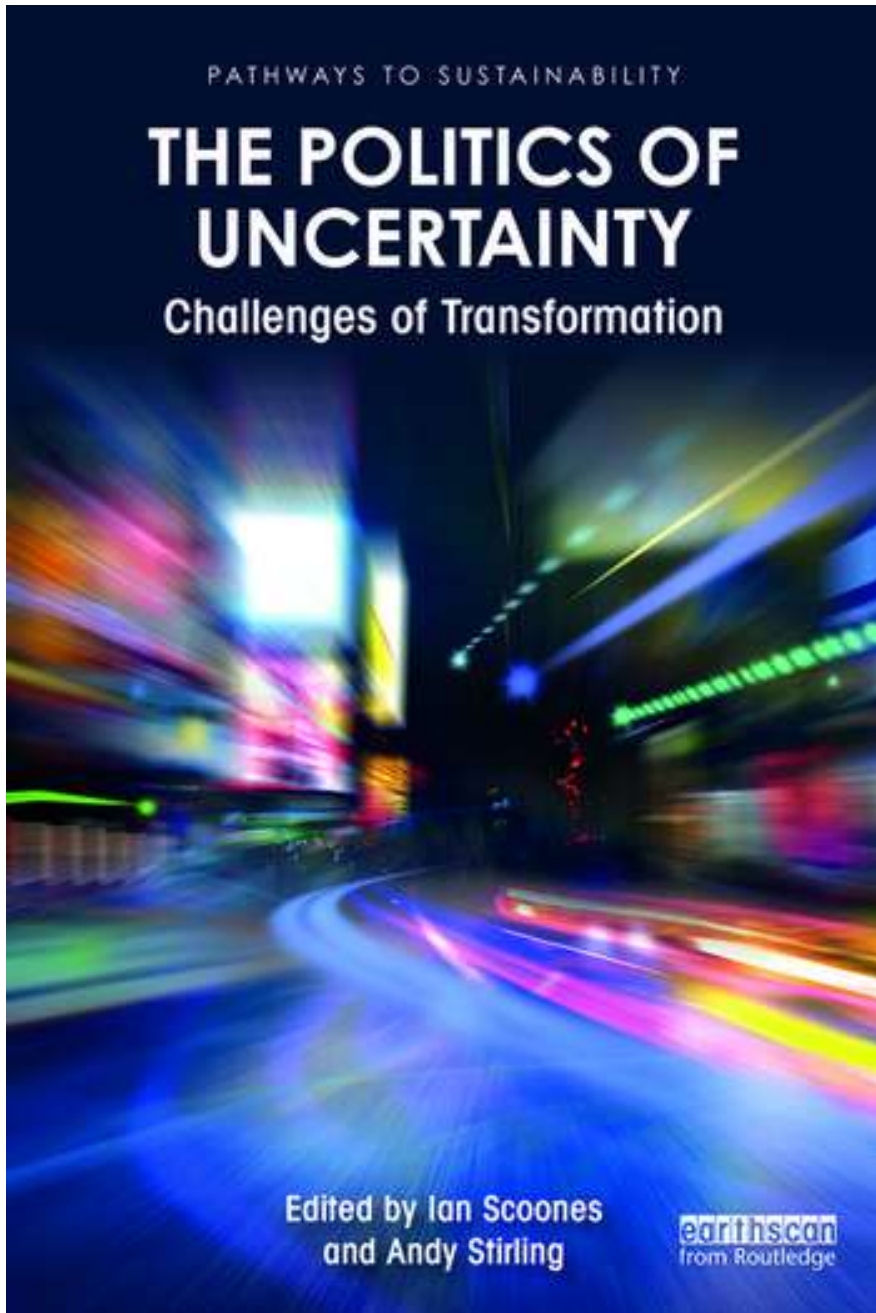
SHARING RISKS OR PROLIFERATING UNCERTAINTIES?

Insurance, disaster and development

Leigh Johnson

Model-based parametric insurance led to dramatic consequences for developing countries experiencing droughts

Open access: <https://www.taylorfrancis.com/books/politics-uncertainty-ian-scoones-andy-stirling/e/10.4324/9781003023845>



European institutions are vulnerable to projects oriented to technological solutions and technological optimism

Chapter

4

THE UNRAVELLING OF TECHNOCRATIC ORTHODOXY?

Contemporary knowledge politics
in technology regulation

Patrick van Zwanenberg

Rayner's (2012) strategies to deal with “uncomfortable knowledge”.

Denial, Dismissal, Diversion, Displacement



Steve Rayner
1953-2020



Model based

Rayner, S., 2012, Uncomfortable knowledge: the social construction of ignorance in science and environmental policy discourses, *Economy and Society*, 41:1, 107–125.

Displacement: “The model we have developed tells us that real progress is being achieved” (The focus is now the model not the problem).

Rayner, S., 2012, Uncomfortable knowledge: the social construction of ignorance in science and environmental policy discourses, *Economy and Society*, 41:1, 107–125.

Example of displacement: Chesapeake Bay Program (CBP) modelling work

“Bay models are used to track nutrient loads to ensure the cap is not exceeded”

➔ The model results – rather than the actual measurements, become the substance of use

Rayner, S., 2012, Uncomfortable knowledge: the social construction of ignorance in science and environmental policy discourses, *Economy and Society*, 41:1, 107–125.

Risk → uncertainty → ignorance → **indeterminacy**

Wynne's indeterminacy: future actions predicated on future generations' willingness — the example of nuclear waste



Brian Wynne

Wynne, B. (1992). Uncertainty and environmental learning 1, 2Reconceiving science and policy in the preventive paradigm. *Global Environmental Change*, **2**(2), 111–127.



1990

Funtowicz & Ravetz: demystifying the mathematics of uncertainty as part of democratising expertise → Post-normal science



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Science for the post-normal age

[Silvio O. Funtowicz](#), [Jerome R. Ravetz](#) [✉](#) [Show more](#) [v](#)

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[10.1016/0016-3287\(93\)90022-L ↗](#)



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Date: September 1993

Pages: 739-755

Volume: [Volume 25](#),

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1990

Uncertainty in policy-relevant science is not a single thing to be minimised. It must be charted (➔ NUSAP). Pretending precision where there is none corrupts the science-policy interface.



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10.1016/0016-3287(93)90022-L



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Futures

Date: September 1993

Pages: 739-755

Volume: Volume 25,

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Mind the assumptions

Assess uncertainty and sensitivity

Mind the hubris

Complexity can be the enemy of relevance

Mind the framing

Match purpose and context

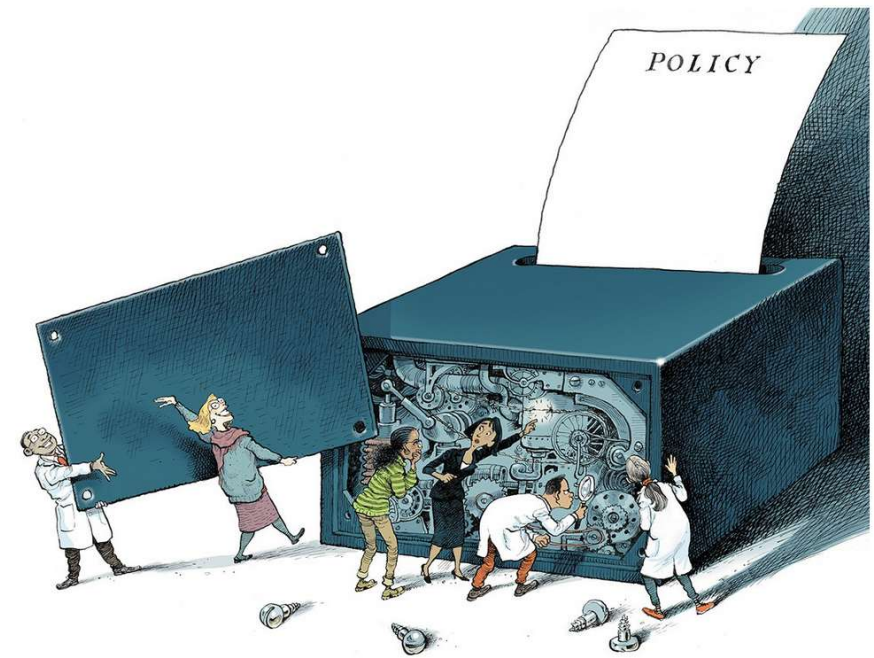
Mind the consequences

Quantification can backfire.



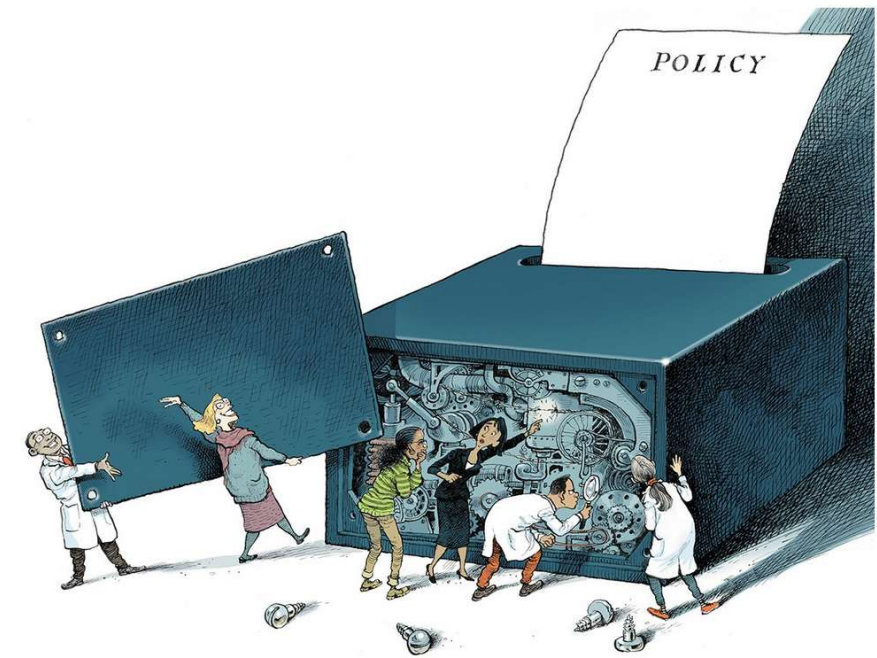
Mind the unknowns

Acknowledge ignorance



Mind the unknowns

Acknowledge ignorance



Source: A. Saltelli, G. Bammer, I. Bruno, et al., Five ways to ensure that models serve society: a manifesto, Nature 582 (2020) 482–484.

From Socrates's “knowing of not knowing” to Nicolaus Cusanus’ Docta Ignorantia, ignorance was a virtue until Descartes

Five ways to ensure that models serve society: a manifesto

Pandemic politics highlight how predictions need to be transparent and humble to invite insight, not blame.



Illustration by David Parkins



nature



nature

Andrea Saltelli , Gabriele Bammer, Isabelle Bruno, Erica Charters, Monica Di Fiore, Emmanuel Didier, Wendy Nelson Espeland, John Kay, Samuele Lo Piano, Deborah Mayo, Roger Pielke Jr, Tommaso Portaluri, Theodore M. Porter, Arnald Puy, Ismael Rafols, Jerome R. Ravetz, Erik Reinert, Daniel Sarewitz, Philip B. Stark, Andrew Stirling, Jeroen van der Sluijs & Paolo Vineis

3 modellers Lo Piano, Puy, Saltelli

2 experts models and society Pielke, van der Sluijs

3 statisticians Mayo, Stark, Portaluri

2 statactivistes Bruno, Didier

2 economists Kay, Raynert

1 epidemiologist Vineis

2 sociologists of quantification

Espeland, Porter

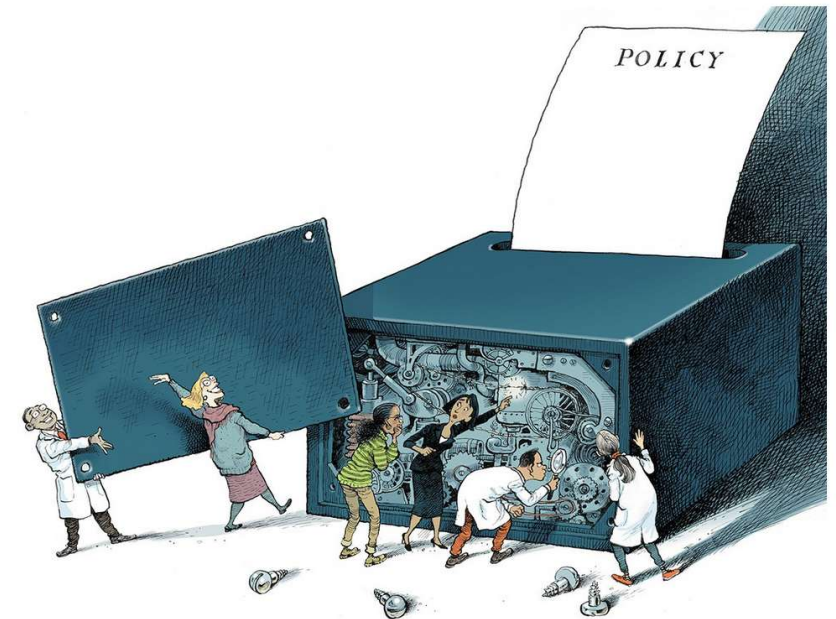
3 STS scholars Bammer, Sarewitz, Stirling

1 philosopher Ravetz

1 historian Charters

1 political scientists Di Fiore

1 expert RRI - Open Science Rafols



PART II — WHERE MODELS COME IN

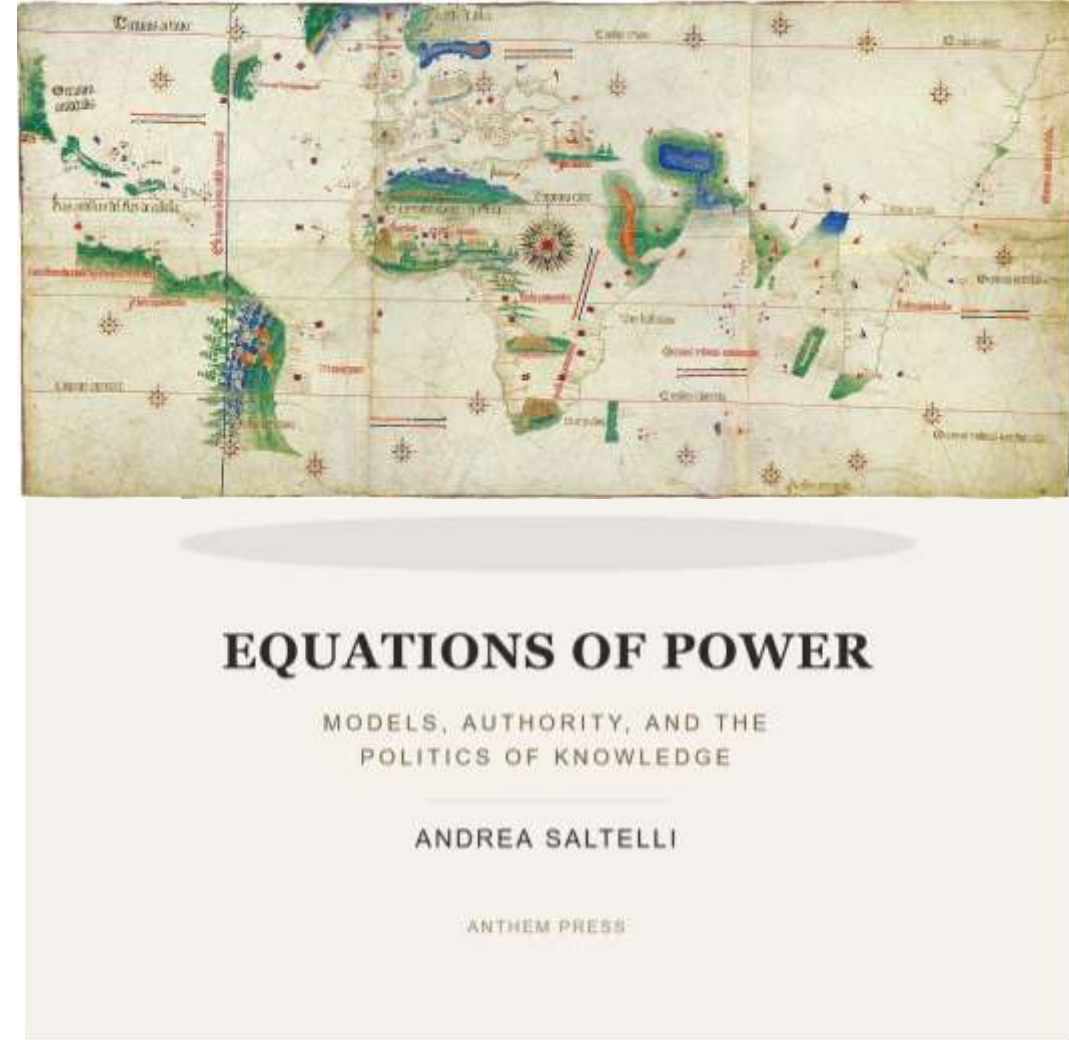
Spoiler alert

A critique of the models you work on. The critique is

- deliberate
- internal
- (possibly) with payoff



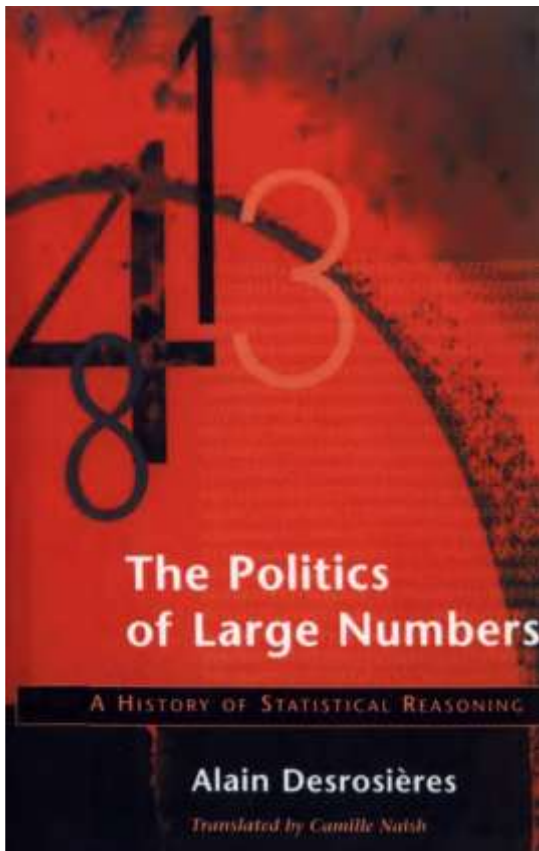
2023



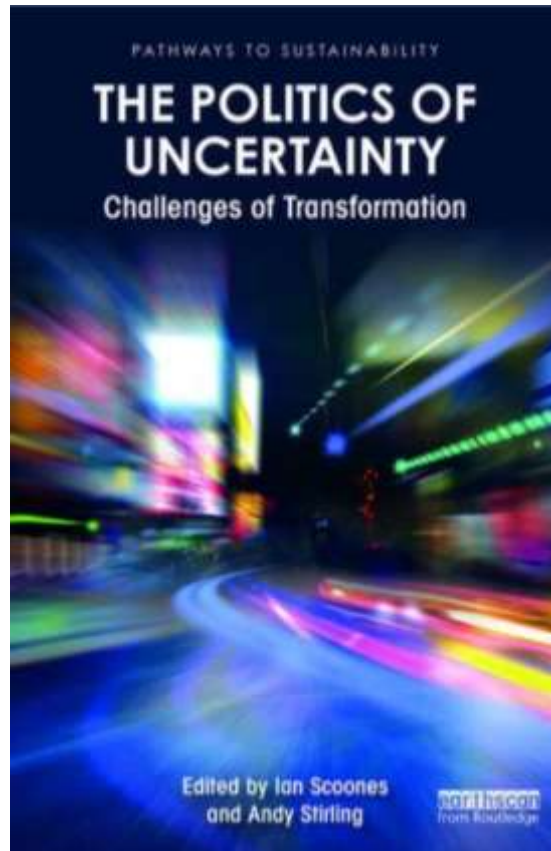
2026

Based on: Equations of Power: Models, Authority,
and the Politics of Knowledge (Anthem Press, 2026)

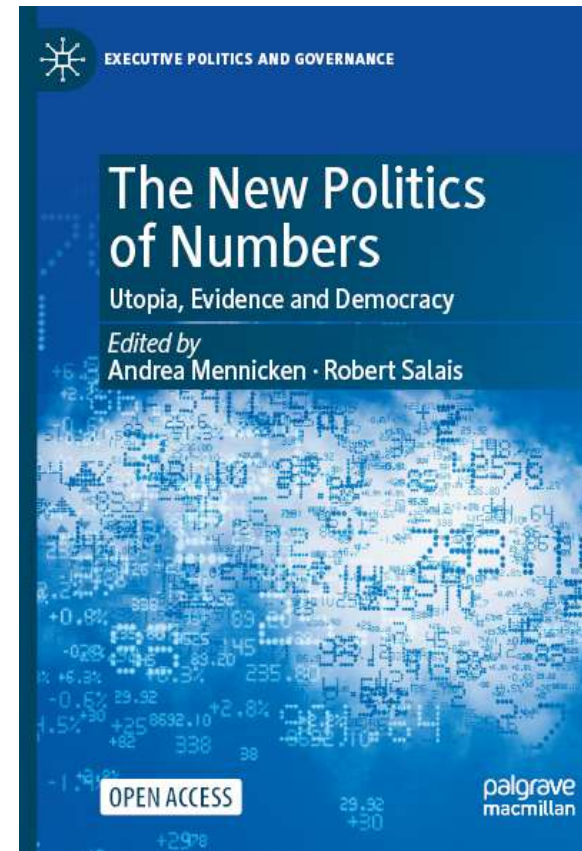
As shown by Rayner's displacement,
uncertainty has a deep relation to policy,
quantification and modelling



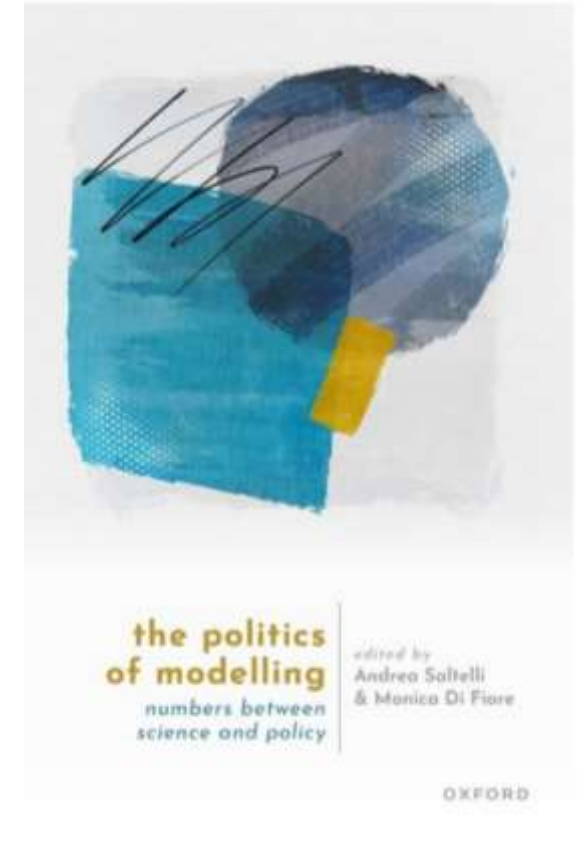
1998
(in English)



2020



2022



2023

Uncertainty, politics and models

What is a model? A philosopher's take

STRUCTURE

Three possibilities:

1. concrete,
2. mathematical,
3. computational

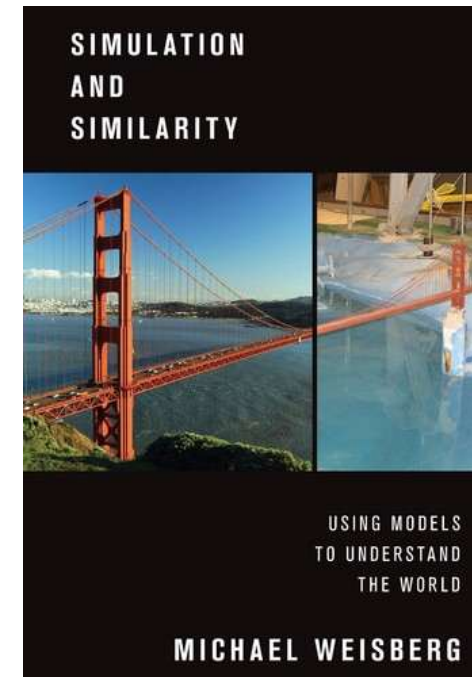
—MODEL DESCRIPTION—



THE WORLD
(target system)

CONSTRUAL

1. assignment,
2. scope,
3. dynamical fidelity,
4. representational fidelity



A philosopher's take

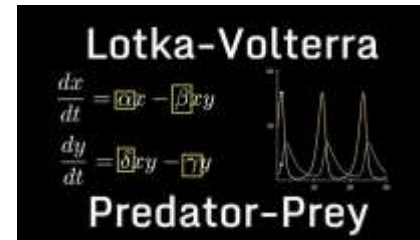
STRUCTURE

Three possibilities:

1. Concrete, physical scale model of San Francisco Bay



2. Mathematical, Lotka-Volterra



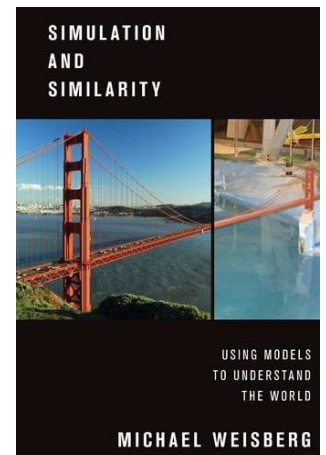
3. Computational, Schelling's segregation model



Dissatisfied because
only 1/4 (25%) of
neighbors are X

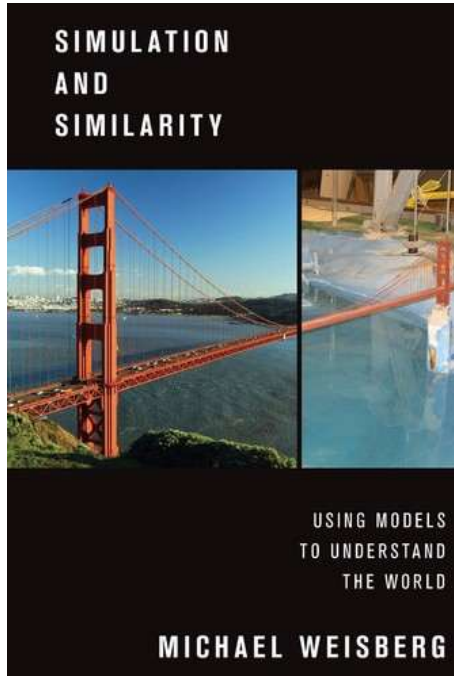
X	X	O	X	O
X	O	O	O	O
X	X			
X	O	X	X	X
X	O	O		O

Source: <http://nifty.stanford.edu/2014/mccown-schelling-model-segregation/>



A philosopher's take

CONSTRUAL



x = Adriatic sardine population

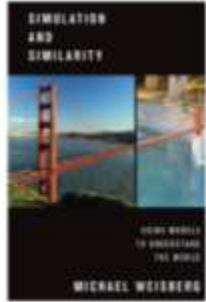
Small pelagic species under moderate exploitation regimes

Does it predict well?

Does it predict well for the right reasons?

- ← 1. assignment,
- ← 2. scope,
- ← 3. dynamical fidelity,
- ← 4. representational fidelity

A philosopher's take



	CONSTRUAL
x = Adriatic sardine population	← 1. assignment,
Small pelagic species under moderate exploitation regimes	← 2. scope,
Does it predict well?	← 3. dynamical fidelity,
Does it predict well for the right reason?	← 4. representational fidelity

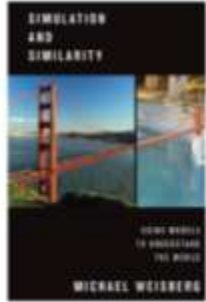
What the construal does not include: a model's telos



A model commissioned by a large industrial conglomerate will differ from one produced by a local fisherman organisation



A philosopher's take



CONSTRUAL

- x = Adriatic sardine population ← 1. assignment,
- Small pelagic species under moderate exploitation regimes ← 2. scope,
- Does it predict well? ← 3. dynamical fidelity,
- Does it predict well for the right reason? ← 4. representational fidelity

Dissatisfied because only 1/4 (25%) of neighbors are X

X	X	O	X	O
	O	O	O	O
X	X			
X	O	X	X	X
X	O	O		O

Source: <http://nifty.stanford.edu/2014/mccown-schelling-model-segregation/>

What the construal does not include: a model's telos

Schelling segregation: an agent moves if fewer than a third of its neighbours are of the same type. The construal is silent on redlining, restrictive covenants, racially selective mortgage lending ...

CONSTRUAL

1. Assignment → Sign
2. Scope → Object
3. ? ← Interpretant

Construal versus Charles Sanders Peirce's triadic conception of the sign as structure connecting three elements

- the sign / *representamen*
- an object
- an “interpretant



Elements for a comprehensive assessment
of public indicators



Paul-Marie Boulanger

2014

Editor: Andrea Saltelli



Author: ELISABETH

<http://publications.jrc.ec.europa.eu/repository/bitstream/JRC92162/lbna26921enn.pdf>

Sign ↔ Cry



Object ↔ Predator



The African vervet monkey
(*Cercopithecus aethiops*)
can distinguish with its
cry the nature of the
predator: aerial (eagle),
terrestrial (leopard),
ground (snake)

Interpretant ↔ Behaviour

↑
↓
Telos



Weisberg gives us the anatomy of a model. What it misses in its political physiology

Models have migrated — from the margins of scientific practice to its epistemic and political core; the COVID and Climate cases



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](#), [Andy Stirling](#), [Massimo Tavoni](#), [Arnald Puy](#)

First published: 26 August 2024 | <https://doi.org/10.1002/wcc.915> | [VIEW METRICS](#)

Edited by Matthias Heymann, Domain Editor and Maria Carmen Lemos, Editor-in-Chief

Behind the Virus Report That Jarred the U.S. and the U.K. to Action

It wasn't so much the numbers themselves, frightening though they were, as who reported them: Imperial College London.

Landler, Mark, and Stephen Castle. 2020. Behind the Virus Report That Jarred the U.S. and the U.K. to Action – The New York Times. In The New York Times. <https://www.nytimes.com/2020/03/17/world/europe/coronavirus-imperial-college-johnson.html>



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Science Under Siege and the Migration of Scientific Authority

Essay Review | [Open access](#) | Published: 11 May 2026
(2026) [Cite this article](#)



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[Andrea Saltelli](#) 

Sections

Scientists have built a 'digital twin' of Earth to predict the future of climate change

The complex computer model takes into account weather and climate systems as well as our impact on the planet.

DestinE is true game changer in our fight against climate change. ”

- Margrethe Vestager -

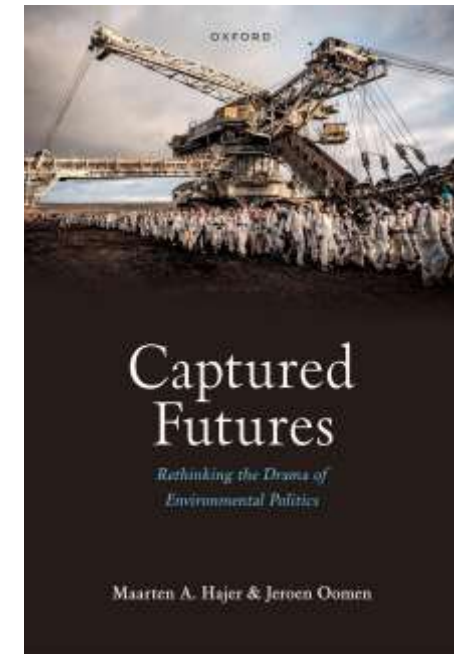
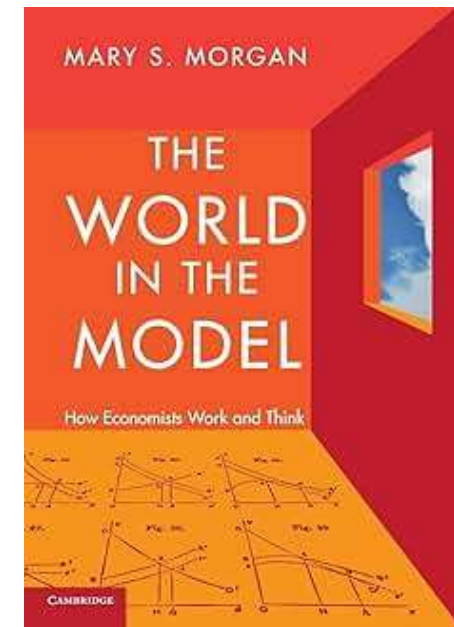
Today, the future is literally at our fingertips

By [Rosie Frost](#) & Angela Symons

Published on 11/06/2024 - 16:00 GMT+2 • Updated 16:00

The political economy of models:

- their potentiality to colonise other worlds, starting from the world in the model (Morgan);
- their capacity of ‘navigating the political’, adapting their inference to an ongoing policy process, thus becoming agents in the process itself (Hajer and Oomen);



The political economy of models:

- their ability to act as chameleons, jumping from a context of investigation to one of prediction, and defending against criticism by reverting to ‘this is just a study model’ (Pfleiderer);
- their political influence being the higher, the more they can be presented as apolitical;
- their opportunity for bringing their topic to the forefront of attention via a process of problematisation (Callon), since they ‘draw toward the centre’ (Latour)

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

Michel Callon. Some elements of a sociology of translation: domestication of the scallops and the fishermen of St Brieuc Bay. *The Sociological Review*, 32(S1):196–233, 1984.



Source: National Geographic



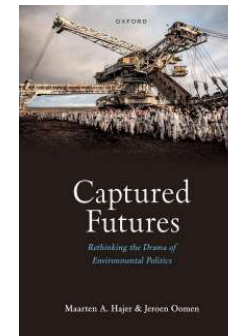
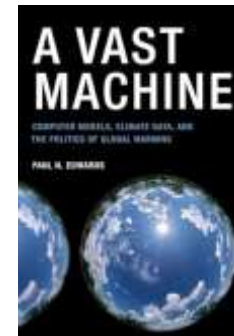
A model constitutes, not merely represents. It *does not describe X; it creates X as an object of political knowledge.*

Examples of X:

University rankings create higher education as a globalised enterprise

Pandemic models create the policies adopted to fight them

IAM creates global climate as we know it

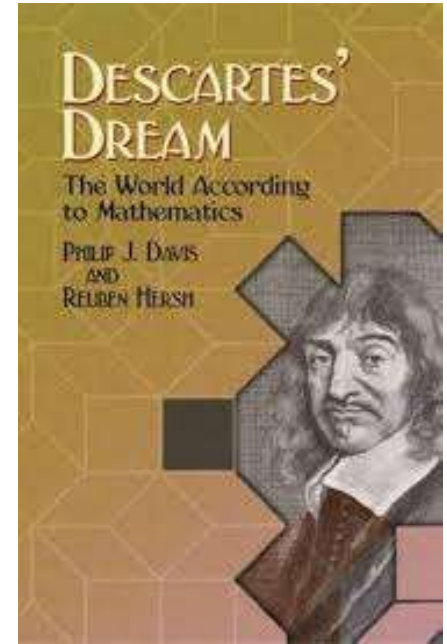




Models derive epistemic authority from mathematics

Are less explored (by sociologists of quantification) than algorithms, AI or indicators

Resist falsification ...

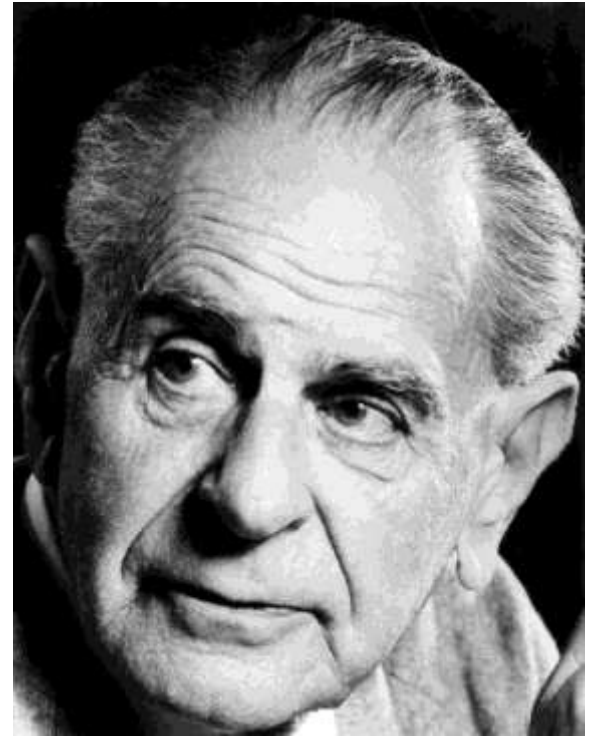


Models that take no risks

The empirical content of a theory is measured by the risks it takes — the observations that could prove it wrong (severe tests)

Climate models projecting the cost of CO₂ to 2300.
Nuclear waste safety models covering a million years.
Digital twins simulating ecosystem dynamics with 50-year horizons

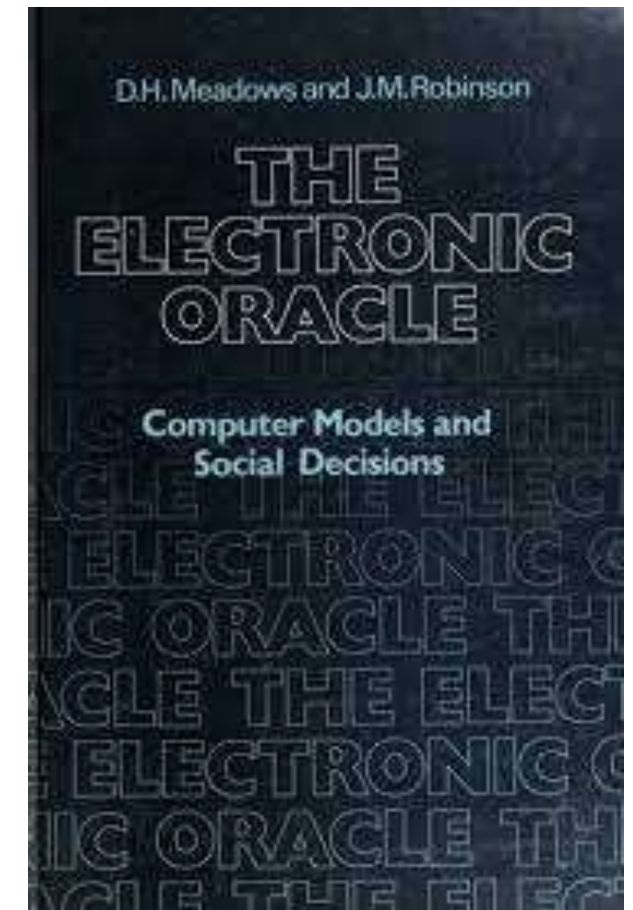
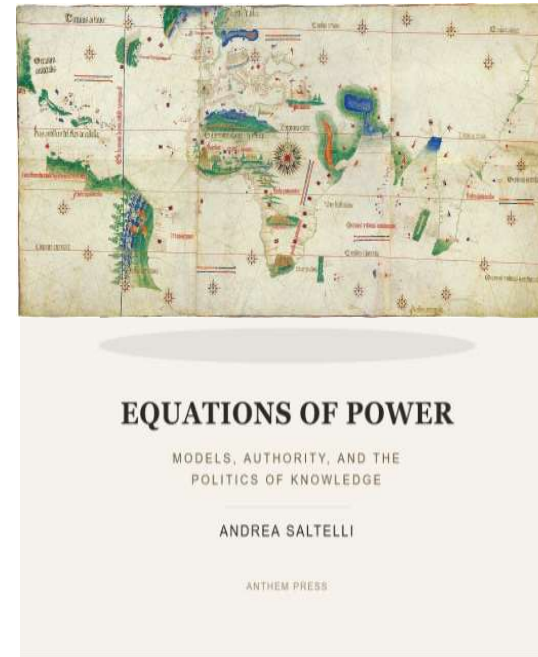
These models take no risks. No severe tests here



Karl Popper
(1902–1994)

Validation methods have historically lacked traction, and Dana Meadows lamented this going on ‘for decades’ in 1985 ... Why?

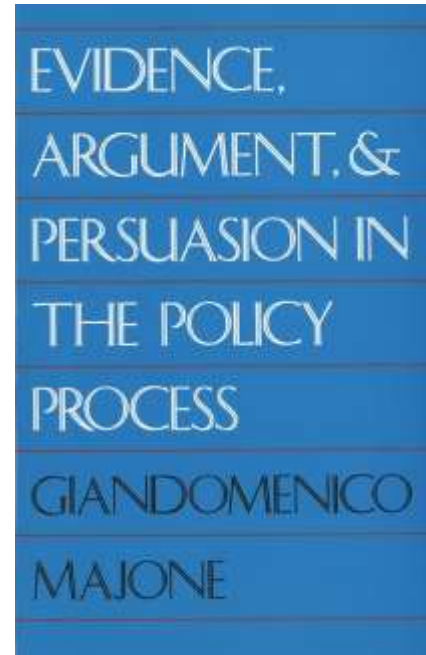
Discussed here



Published in 1985

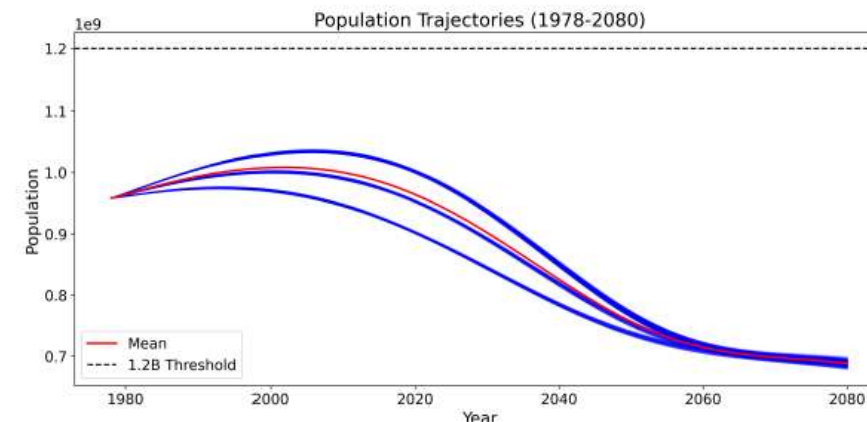


Giandomenico Majone



“Are the results from a particular model more sensitive to changes in the model and the methods used to estimate its parameters, or to changes in the data?”

The Song Jian / one-child policy 1980's model. We find near-insensitivity to inputs ...



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What Demographic Prediction Can and Cannot Achieve

14 Pages • Posted: 19 May 2026

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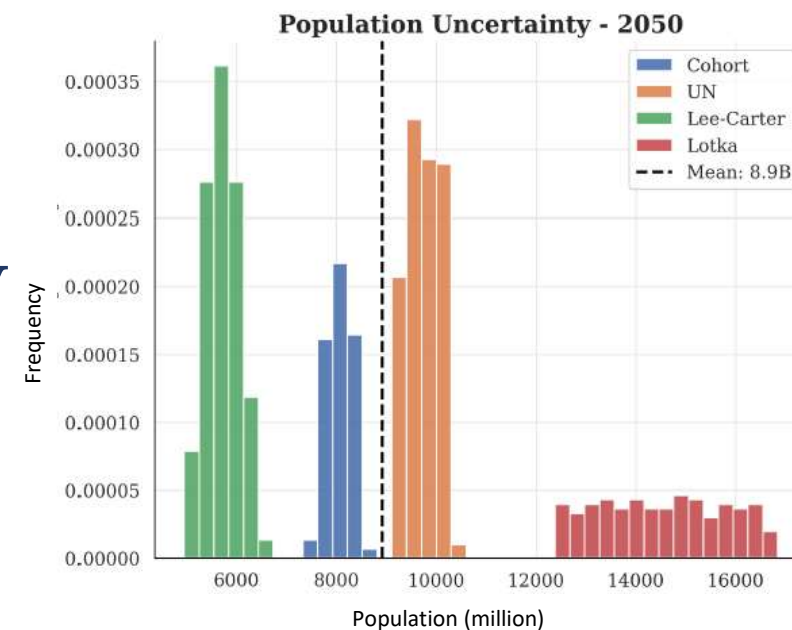
University of Colorado at Boulder

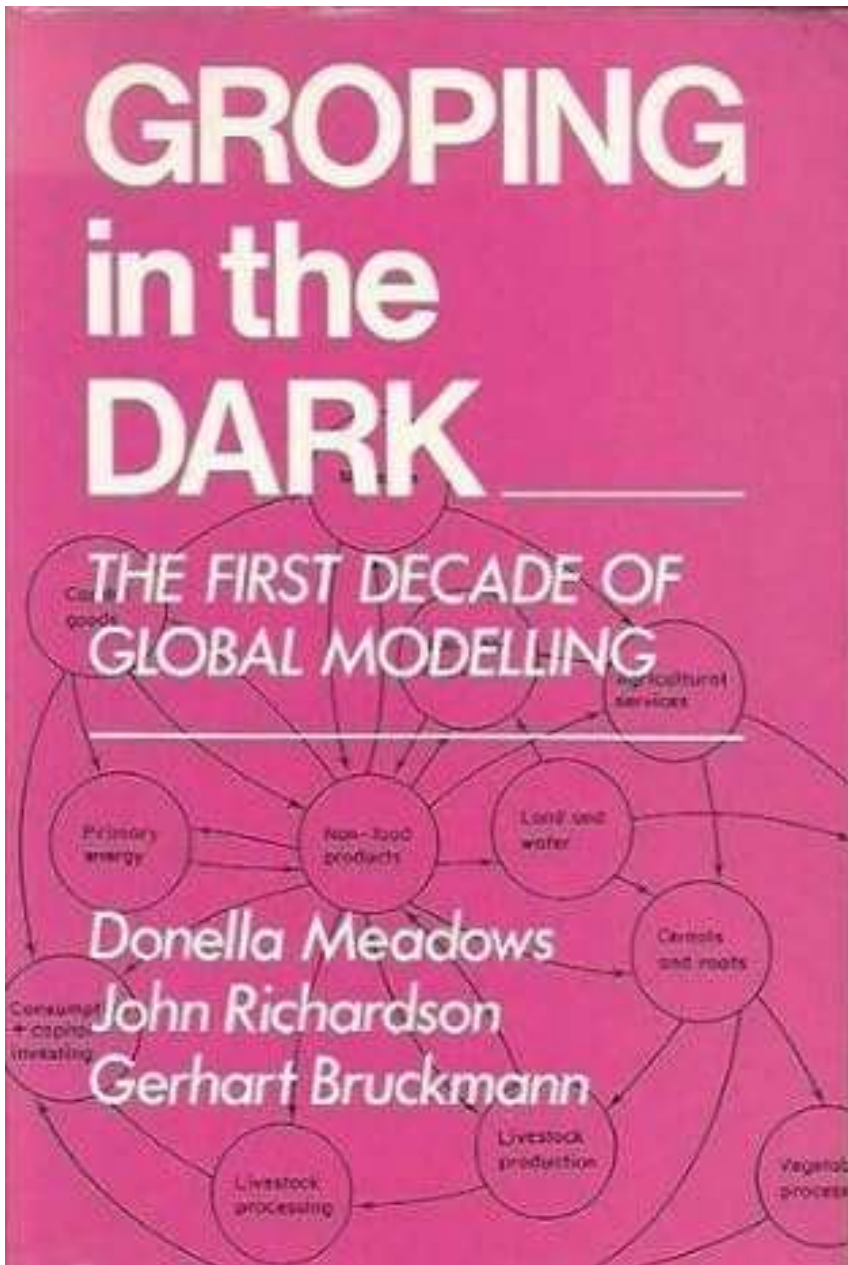
[Andrea Saltelli](#)

UPF Barcelona School of Management

Date Written: May 15, 2026

... and projections **today in use** are dramatically model-dependent





1982

“We define ‘sensitive’ in a way that does not appear to be widely shared in the modelling community. We call a parameter sensitive **not** when a change in it changes the value of an output number but when it changes the policy conclusions we would draw from the model” (p. 132)



Memento interpretant



Leo Breiman
1928–2005

Enters Leo Breiman's 'Two cultures' work

“The goal is not interpretability,
but accurate information”

➔ Embrace model-agnostic algorithmic culture that
prioritizes empirical predictive accuracy

Leo Breiman. Statistical Modeling: The Two Cultures
Statistical Science, 16(3):199–231, August 2001



Two cultures

The Data Modelling Culture

Data are generated by a specific stochastic model; estimate its parameters.

The Algorithmic Modelling Culture

The data-generating mechanism is unknown; focus on predictive accuracy using algorithms.

Leo Breiman. Statistical Modeling: The Two Cultures
Statistical Science, 16(3):199–231, August 2001



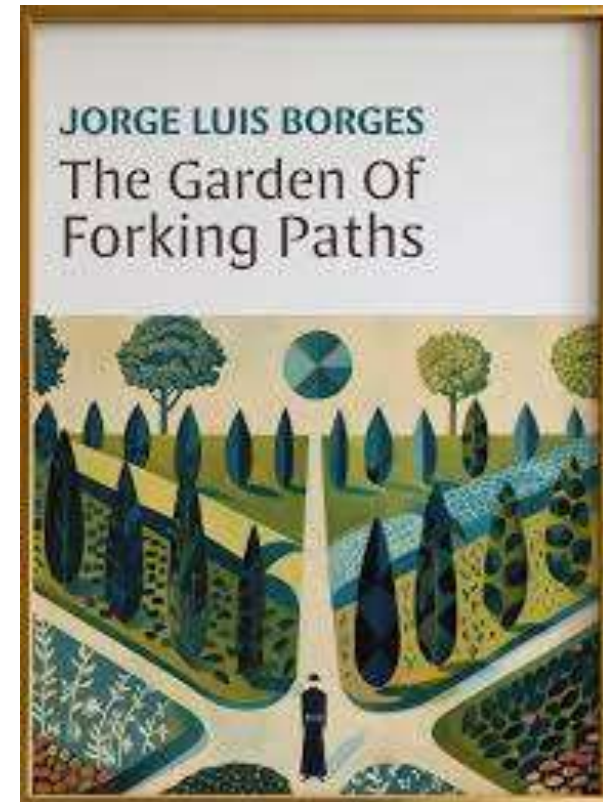
The Algorithmic Modelling Culture

Provided an epistemological justification for machine learning and, in time, AI



The Data Modelling Culture

Discovered the 'Garden of Forking Paths'; opened the season of multi-analyst experiments and multiverse analysis



Fishing expeditions? Forking paths?



Vincent van Gogh, Fishing Boats at Sea, source: <https://www.wikiart.org/>



Jorge Luis Borges
(1899–1986)



Taking different
narratives within the
same novel like Ts'ui Pên



The garden of forking paths: Why multiple comparisons can be a problem, even when there is no “fishing expedition” or “p-hacking” and the research hypothesis was posited ahead of time*

Andrew Gelman[†] and Eric Loken[‡]

14 Nov 2013

Many multi-analyst studies ongoing, e.g.:

“Are soccer players with dark skin tone more likely to receive red cards from referees?”, Silberzahn et al. 2018

“Is there an impact of compulsory schooling on teenage pregnancy rates?”, Huntington-Klein et al. (2021)



Source: BBC <https://www.bbc.com/sport/football/68435064>

HUNTINGTON-KLEIN, N., ARENAS, A., BEAM, E., BERTONI, M., BLOEM, J. R., BURLI, P., CHEN, N., GRIECO, P., EKPE, G., PUGATCH, T. et al. (2021). The influence of hidden researcher decisions in applied microeconomics. *Economic Inquiry* 59 944–960.

SILBERZAHN, R., UHLMANN, E. L., MARTIN, D. P., ANSELMINI, P., AUST, F., AWTRY, E., BAHNÍK, Š., BAI, F., BANNARD, C., BONNIER, E. et al. (2018). Many analysts, one data set: Making transparent how variations in analytic choices affect results. *Advances in Methods and Practices in Psychological Science* 1, 337–356.

Multi-analyst and multiverse analyses, exploratory modelling analysis tell us how sensitive conclusions are to the paths taken ...

... But was the right garden entered in the first place?



PART III — SENSITIVITY AUDITING

Sensitivity auditing: “Sensitivity auditing is a wider consideration of the effect of all types of uncertainty, including structural assumptions embedded in the model, and subjective decisions taken in the framing of the problem” (European Commission, 2021).



Better Regulation
TOOLBOX

November 2021

European Commission. November 2021. “Better Regulation: Guidelines and Toolbox.”
https://ec.europa.eu/info/law/law-making-process/planning-and-proposing-law/better-regulation-why-and-how/better-regulation-guidelines-and-toolbox_en

1. Check against rhetorical use of mathematical modelling
2. Adopt an 'assumption hunting' attitude
3. Detect garbage in, garbage out (GIGO)
4. Find sensitive assumptions before they find you
5. Aim for transparency
6. Do the right sums
7. Focus the analysis on the key question answered by the model, exploring the entire space of the assumptions holistically



Verbatim from

Int. J. Foresight and Innovation Policy, Vol. 9, Nos. 2/3/4, 2013

213

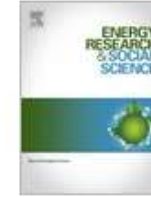
What do I make of your latinorum? Sensitivity auditing of mathematical modelling

An example of applying Rule 1: rhetorical use of models



Energy Research & Social Science

Volume 127, September 2025, 104296



Original research article

Energy policy-making in the European Union between past and present ☆

Samuele Lo Piano^{a b}  , Andrea Saltelli^{b c}

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<https://doi.org/10.1016/j.erss.2025.104296> ↗

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The institutional context of science, models, and policy: The IIASA energy study

Published: September 1984

Volume 17, pages 277–320, (1984) [Cite this article](#)



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



A fast breeder reactor (a crucial ingredient of the energy mix predicted for the year 2030 by IIASA) is today an amusement park in the Netherlands

Applying sensitivity auditing to different cases:



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Unpacking the modelling process via sensitivity auditing

Samuele Lo Piano ^a, Razi Sheikholeslami ^b, Arnold Puy ^{c, d, *}, Andrea Saltelli ^f [Show more](#) [▼]

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- Nutrition and Public Health
- Sustainability, Ecological Footprint (EF)
- Global Hydrological Models
- Sociohydrology, Coupled Human and Water Systems (CHAWS)
- Food Security
- Education, Programme for International Student Assessment (PISA) test

The same pattern appears:

- the most consequential choices are often not numerical;
- they concern problem framing, indicator selection, omitted variables, boundary choices, and implicit values

What would help

A model should not be used for policy unless:

- Its **sensitivity** to key assumptions has been explored
- Its structural and **framing** choices have been made explicit and tested
- **Affected parties** have had the opportunity to identify which assumptions matter to them

Global
sensitivity
analysis

Modelling
of the
modelling
process

Sensitivity
auditing

Alternatives: Statactivism and counter-modelling

- Statactivists: societal mobilisation around alternative numbers
- Countermodelling: building models that respond to different framings
- Critical friends: engaging with modelling communities from within (➔ remember the spoiler alert)
- Observatories: permanent watchdog institutions for quantification

Latest papers



Science Under Siege and the Migration of Scientific Authority

Mann and Hotez's siege narrative defending science illustrates the very transformation it opposes: scientific authority increasingly migrates into model-mediated, politically contested terrain, reinforcing polarisation.

Models and the common good

A short analysis of norms and counter-norms in modelling, discussing how models may misuse their epistemic authority for reasons of occasion, opportunity and interest.

Outline:

Narratives and counter-narratives, State of



Linkedin feed



END

