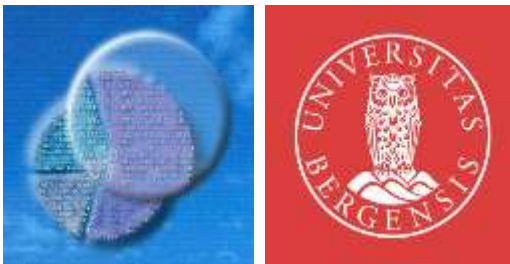


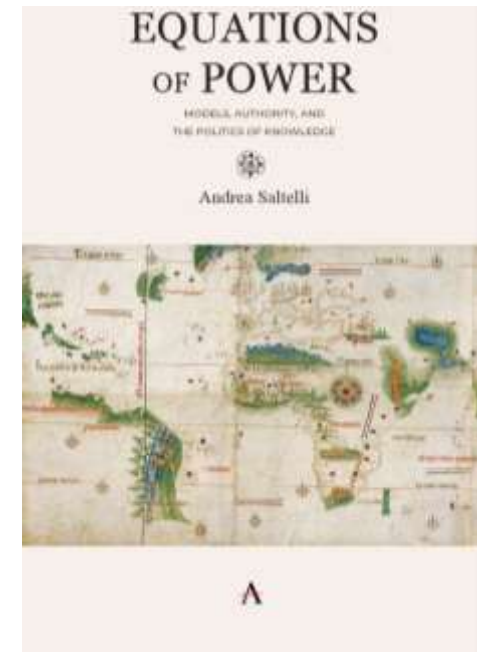
Responsible Modelling and Forecasting

Course SGD 207, Bergen, October 29, 2026

Andrea Saltelli



Based on Equations of Power:
Models, Authority, and the Politics
of Knowledge (Anthem Press, 2027)



Do we live immersed in
fantastic numbers?

‘The Most Important Number You’ve Never Heard Of’

Sept. 17, 2021

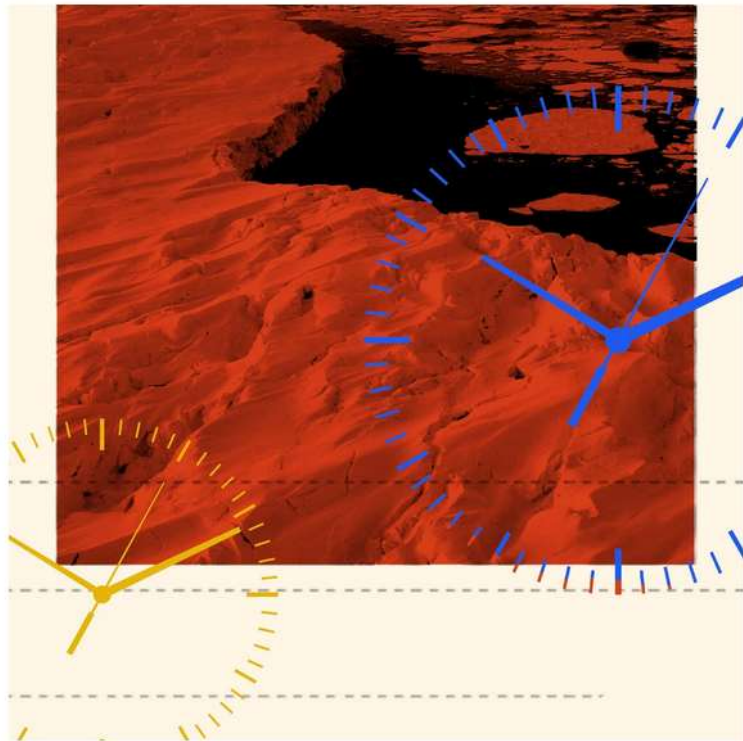


Illustration by Arsh Raziuddin, The New York Times

“social cost of carbon:

=\$56 a ton on average at a 3 percent discount rate

=\$171 a ton on average at a 2 percent discount rate”

The New York Times

Social cost of carbon estimates have increased over time

Richard S. J. Tol

Received: 3 August 2022

Accepted: 23 April 2023

Published online: 15 May 2023

 Check for updates

Mathematical models predicting the damage in dollars from hurricanes and draughts up to the year 2300

The Social Cost of Carbon: Advances in Long-Term Probabilistic Projections of Population, GDP, Emissions, and Discount Rates

Kevin Rennert, Brian C. Prest, William A. Pizer, Richard G. Newell, David Anthoff, Cora Kingdon, Lisa Rennels, Roger Cooke, Adrian E. Raftery, Hana Ševčíková, and Frank Errickson

Working Paper 21-28
October 2021

The paradox of the far future

By Popper's measure, models that project their predictions into a future beyond immediate verification — climate to 2300, nuclear safety to a million years, planetary digital twins — have low empirical content: they forbid nothing that could be checked, and hence take no risks.

“The paradox is that the models claiming the most are, in Popper's sense, the least exposed to refutation — and therefore the least scientific, even as they command the greatest political authority.”

Part I – Why models are special: a state of exception

Mathematical models: a state of exception?

nature

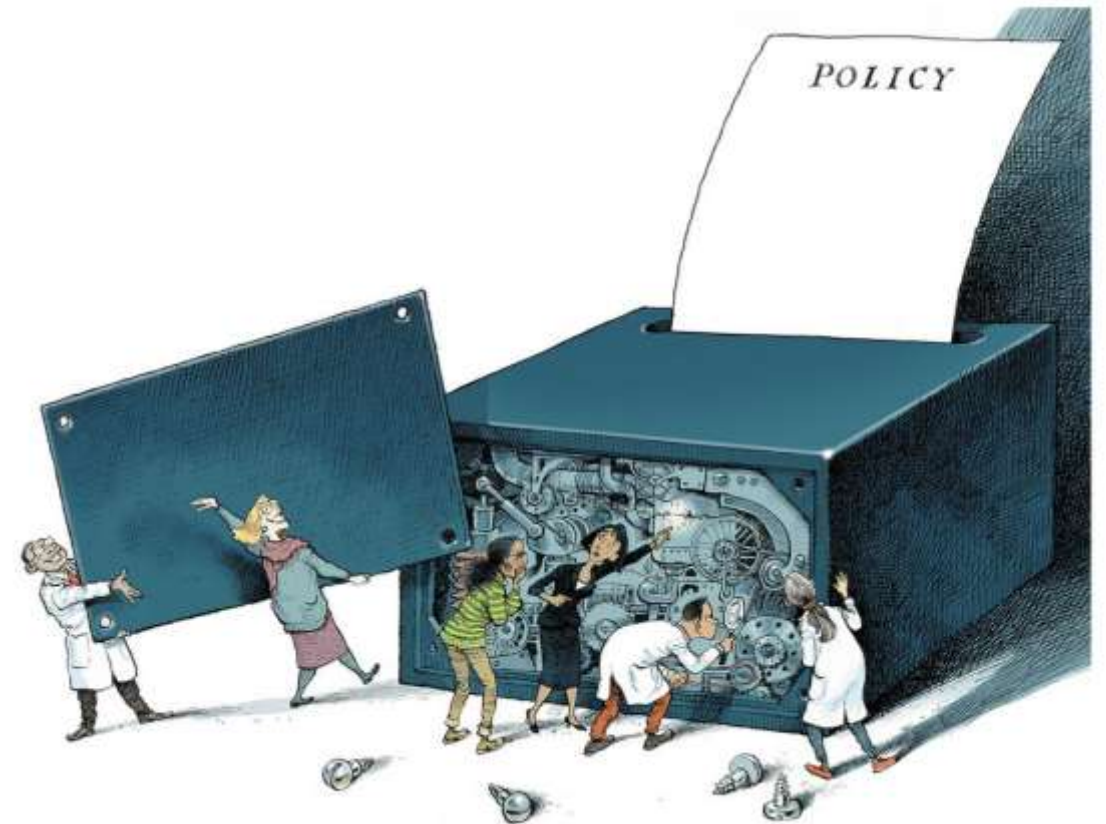
[Explore content](#) ▾ [About the journal](#) ▾ [Publish with us](#) ▾ [Subscribe](#)

[nature](#) > [comment](#) > article

COMMENT | 24 June 2020

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.



Going unnoticed

So far, models have largely escaped the societal alarm reserved for algorithms and artificial intelligence.

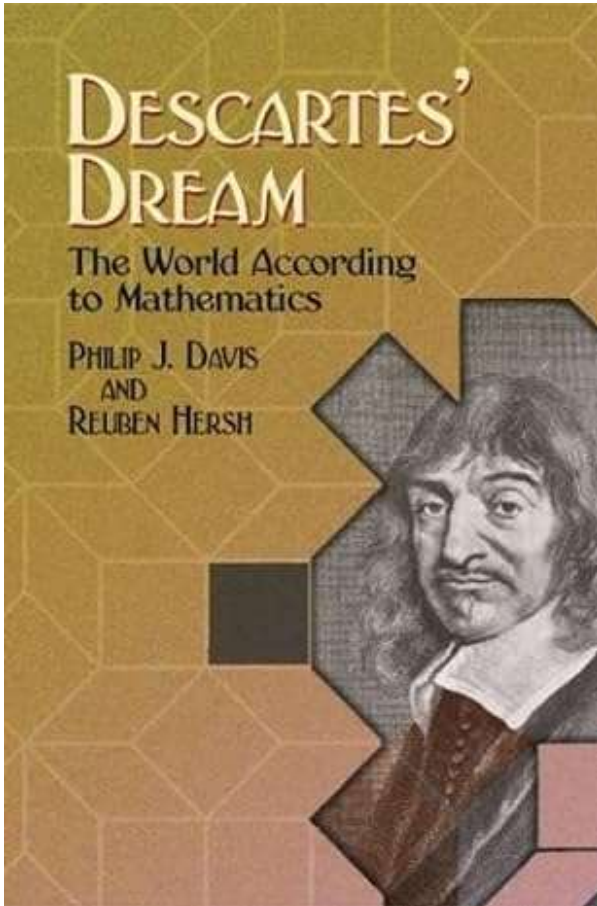
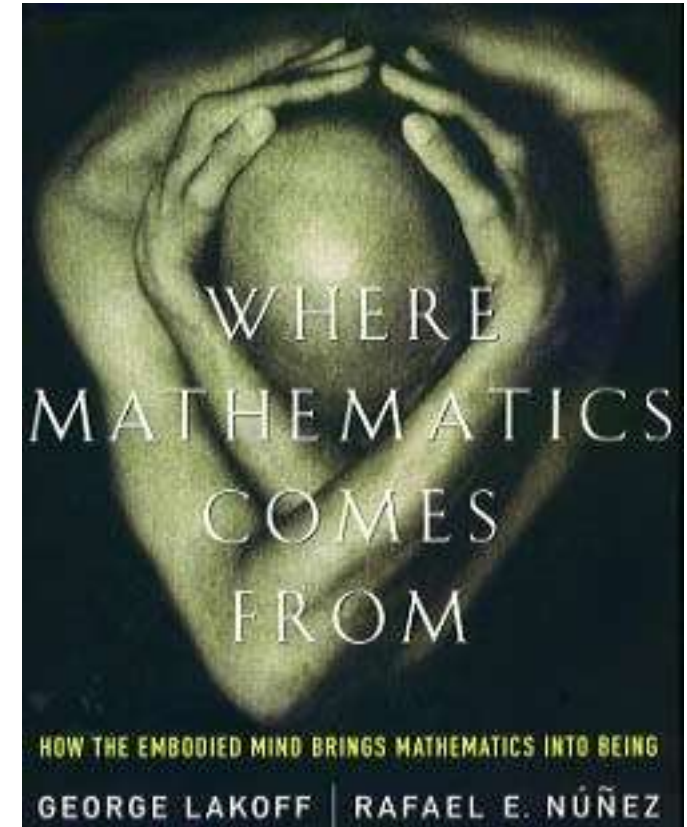
They are shielded by the epistemic authority conveyed by their association with mathematics: only during the last pandemic did media and society take notice of their power, and of the associated dangers.

Before COVID-19, discussions of models as risky or problematic were typically held among experts or practitioners.

Epistemic authority

“[...] the magical (in the anthropological sense) component of computer simulation models: the apparent rigor and infallibility of computer models gave them a prestige and credibility with the public and decision-makers (at least at the time) well beyond other forms of interpreting and presenting information.”

Gilberto Gallopín, on the first world models of the 1970s

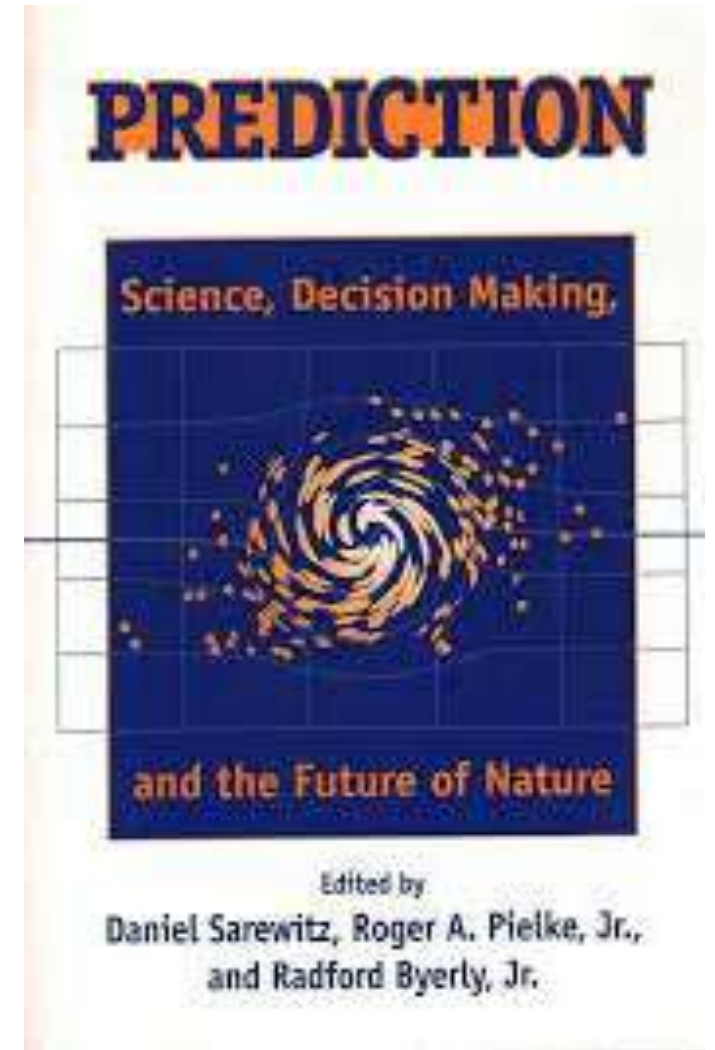


Difficult to prove wrong

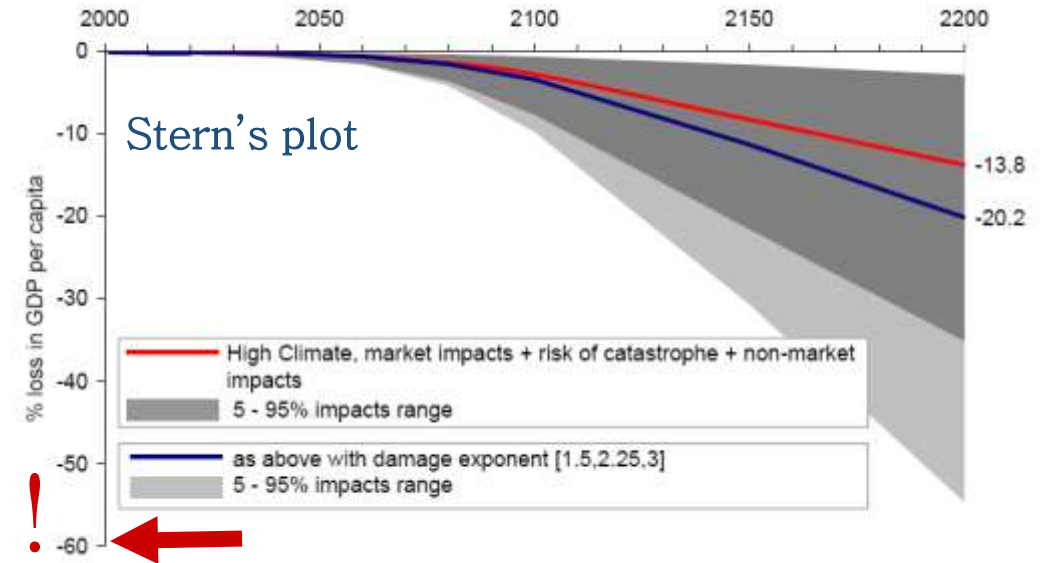
“A model may confirm our biases and support incorrect intuitions. Therefore, models are most useful when they are used to challenge existing formulations, rather than to validate or verify them. Any scientist who is asked to use a model to verify or validate a predetermined result should be suspicious.” (Oreskes et al., 1994)

Hydrologists, 1981

“[...] with judicious fiddling, can be made to produce virtually any desired behaviour, often with both plausible structure and parameter values.”



The Stern–Nordhaus controversy;
 a reverse engineering the model:
 → uncertainty is too large to take
 decisions → both Stern and
 Nordhaus are wrong



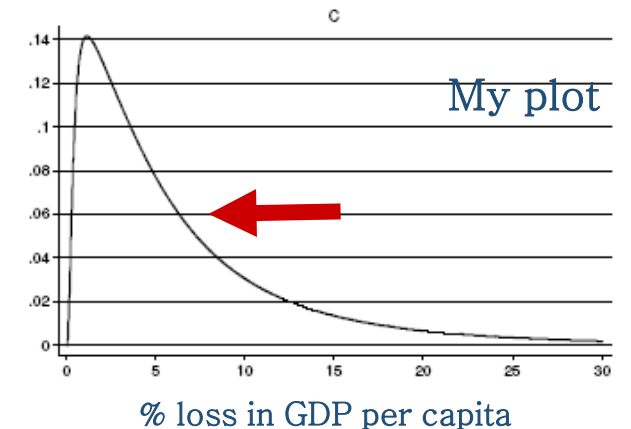
Global Environmental Change 20 (2010) 298–302



Contents lists available at ScienceDirect

Global Environmental Change

journal homepage: www.elsevier.com/locate/gloenvcha



Sensitivity analysis didn't help. A practitioner's critique of the Stern review

Andrea Saltelli*, Beatrice D'Hombres

Joint Research Centre, Institute for the Protection and Security of the Citizen, Ispra, Italy

Consequences descending from state of exception

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.

nature communications

Comment | [Open access](#) | Published: 27 August 2019

A short comment on statistical versus mathematical modelling

[Andrea Saltelli](#)

Nature Communications **10**, Article number: 3870 (2019) | [Cite this article](#)

ScienceAdvances

[Current Issue](#) [First release papers](#) [Archive](#) [About](#)

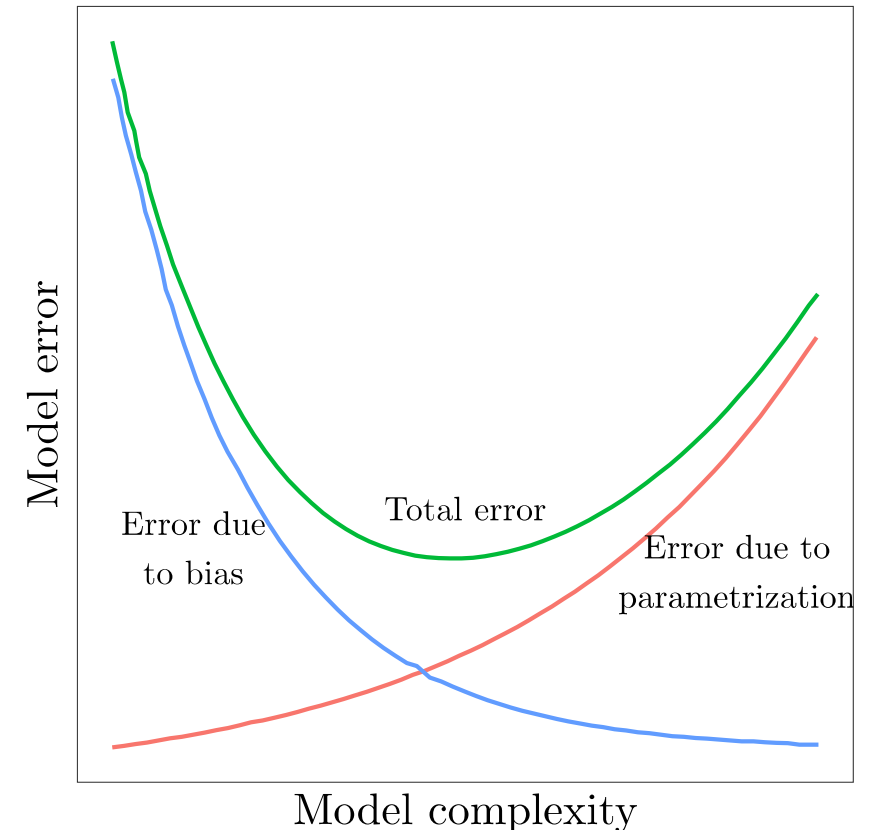
HOME > SCIENCE ADVANCES > VOL. 8, NO. 42 > MODELS WITH HIGHER EFFECTIVE DIMENSIONS TEND TO PRODUCE MORE UNCERTAIN ESTIMATES

RESEARCH ARTICLE | MATHEMATICS



Models with higher effective dimensions tend to produce more uncertain estimates

ARNALD PUY, PIERFRANCESCO BENEVENTANO, SIMON A. LEVIN, SAMUELE LO PIANO, TOMMASO PORTALURI, AND ANDREA SALTIELLI [Authors Info &](#)



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.

Symbiotic to data

Large models at times co-evolve with the data libraries used for their calibration — an ‘incestuous’ model/data symbiosis, whereby the data cannot be used to verify the quality of the model.

“Raw data is an oxymoron”

*“Without models, there are
no data”*

Quips credited to historian Paul N. Edwards

Too assertive

Testing model claims against the quality of evidence across disciplines: is the assertiveness of modellers comparable to that of physics metrology, a supposedly high-quality data field?

The confidence displayed by water modellers matched or surpassed that seen in the most accurate physical sciences.

Not a single feature, but a syndrome

Go unnoticed

Resist
falsification

Accumulate
uncertainty

Co-evolve
with their
data

Display
unwarranted
confidence

“The state of exception, then, is not a single feature but a syndrome: models go unnoticed, resist falsification, accumulate uncertainty, co-evolve with their data, and display a confidence that their evidence base does not always warrant.”

Part II – Energy futures, then and now

[Home](#) > [Policy Sciences](#) > [Article](#)

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 ...



See a summary here

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



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}

[Show more](#) ▾

Looking inside the IIASA models

Model 1

never developed

Model 2

did not work as specified

Model 3

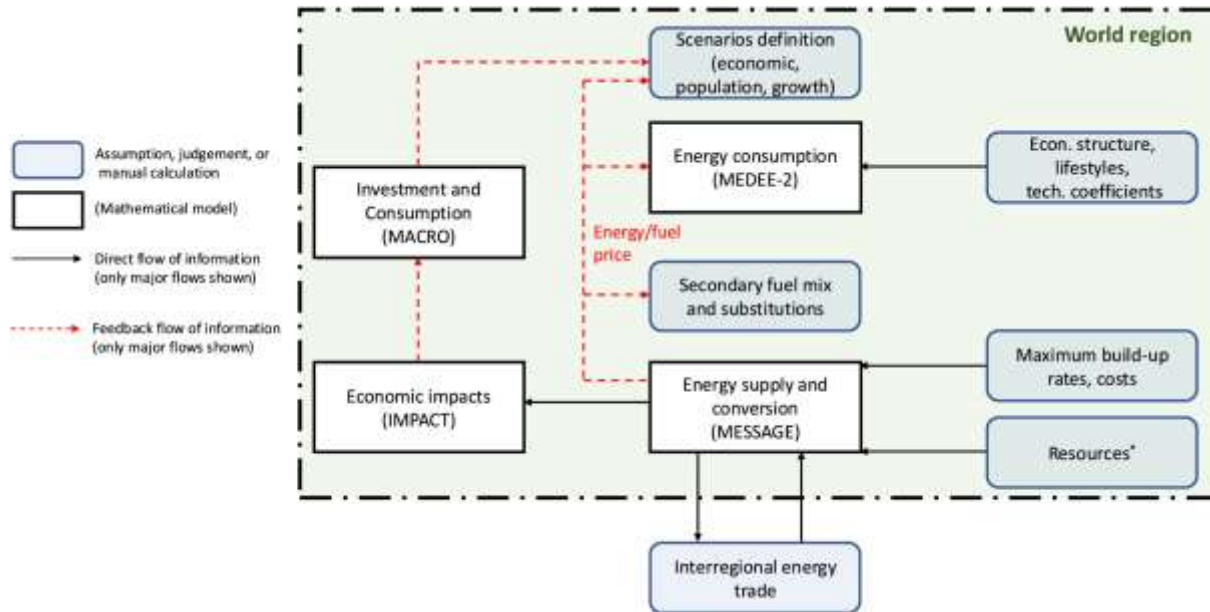
run under constraints to produce the inference that was desired

The relative price of different energy options was not included in the analysis, as the output was too sensitive to them.

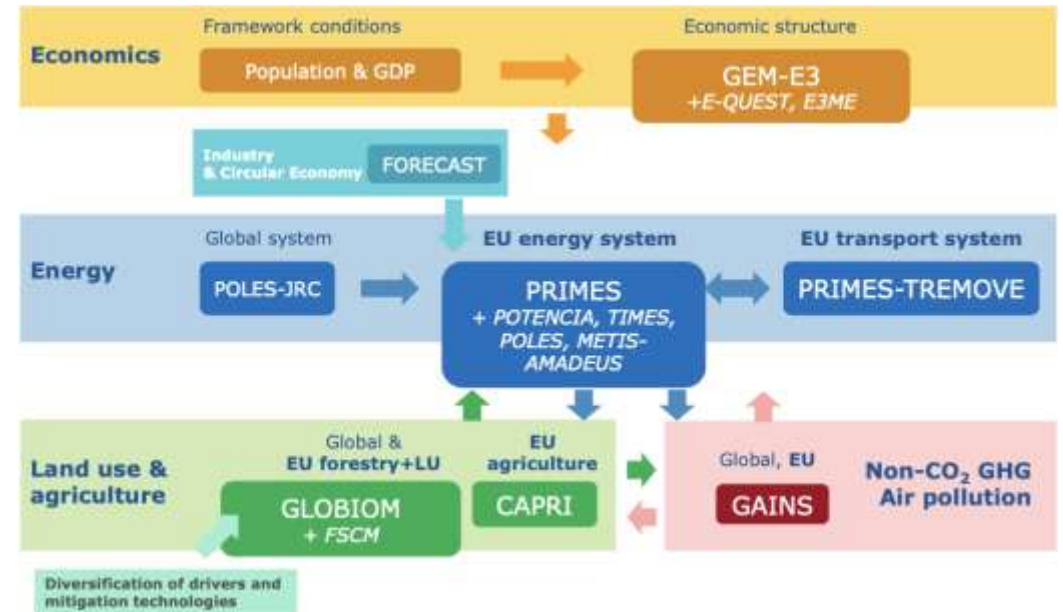
By 2030 we should be getting our energy from fast breeder reactors, centralised solar plants and synthetic fuel from carbon. **None of these, in fact, plays a significant role today.**

- We contrast a 1980s energy study and a 2024 EU impact assessment on emissions.
- Auditing reveals persistent flaws when models are used to inform policy.

IIASA
1980's



EC 2024



The rhetoric of the concatenated suite of models

Then and now: an almost point-by-point symmetry

	IIASA, 1981	EU 2040 climate target, 2024
Concatenated models	Three ‘interconnected’ models: one never developed, one not working as specified	Coupling more rhetorical than substantial; no integrated runs; sensitivity explored only piece-wise
Policy-based assumptions	Demonstrating the feasibility of fast-breeder reactors	Demonstrating a smooth transition to a carbon-free Europe; winners and losers not identified
Opacity	An insider (Keepin) could examine the inner workings	The software in use is proprietary

Lo Piano, S., Saltelli, A. (2025). Energy policy-making in the European Union between past and present. Energy Research & Social Science, 127, 104296.
European Commission (2024). Securing our future: Europe’s 2040 climate target, SWD(2024) 63.

Not a failed forecast: an aura of inevitability

“What is interesting here is not the failure in the prediction — it is legitimate for a foresight to be off the mark — but the fact that a speculative modelling study was presented with an aura of inevitability.”

Collingridge (1980)

A technology is easy to control while its consequences are still unknown, and impossible to control once they are known and entrenched.

A question

Do we need to wait thirty years to find out whether the EU emission pathways were on track?

“More confident that we can model it”

“I am not more confident that we can reach it [a 1.5 °C temperature increase target], but I am more confident that we can model it. [...] we would never have to say it would not be achievable, we just put more negative emissions in.”

An integrated assessment modeller (interview 18)

Integrated assessment models do not describe climate impacts decades ahead; they create them as an object of political and public knowledge.

Who writes the scenarios?

~200

researchers

~15

institutions, led by IIASA and
PIK

556

IPCC AR6 mitigation scenarios
analysed for equity

Pielke Jr. (2026)

The community behind the scenarios used by the IPCC, central banks and governments operates without published terms of reference, conflict-of-interest disclosure, representational balance or public comment.

Kanitkar et al. (2024)

The scenarios' assumptions perpetuate North-South inequality: per-capita GDP in regions with 60% of the world's population stays below the global average even in 2050.

Projective, not predictive

“In the case of climate modelling, which has been prominent in the public debate, the many and varied ‘projective’ scenarios (that is, explorations of plausible futures using computer models conditioned on numerous assumptions and simplifications) are sufficient to undergird just about any view of the future that one prefers. But the ‘projective’ models they produce have frequently been conflated implicitly and sometimes wilfully with what politicians really want, namely ‘predictive’ scenarios: that is, precise forecasts of the future.”

Scenarios of decarbonisation, carbon budgets, and temperature targets emerge from modelling practices that translate heterogeneous processes—biological, physical, economic, and social—into tractable computational form

Sage Journals Search this journal ▼ Enter search terms... [Advanced search](#)

Browse by discipline ▼ Information for ▼

Social Studies of Science

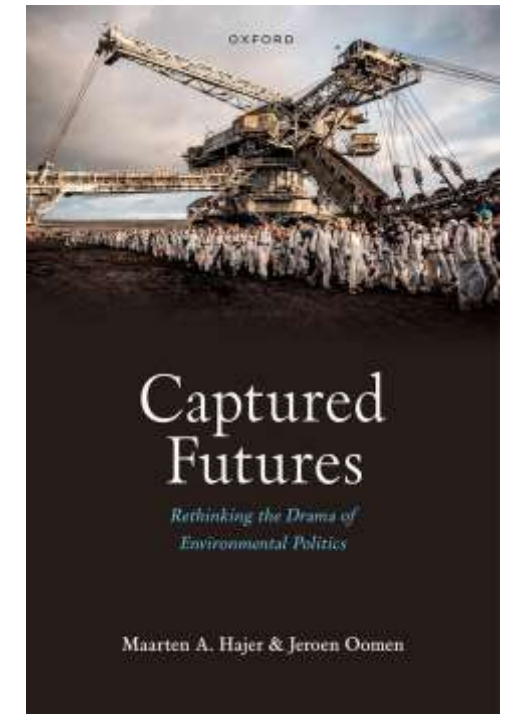
Impact Factor: **2.7** / 5-Year Impact Factor: **3.4**

Open access | Research article | First published online March 21, 2024

Digital twins and the digital logics of biodiversity

[Michelle Westerlaken](#) [View all authors and affiliations](#)

[Volume 54, Issue 4](#) | <https://doi.org/10.1177/03063127241236809>



- Modelling funnels debate toward specific policy options.
- Technological solutionism (carbon capture, hydrogen economy, geoengineering).
- Narrative “scripts” that structure how environmental futures are imagined.

Part III – When a model counts one variable

Counting one variable

Biofuels

Lifecycle models accounted for the carbon saved at the tailpipe while ignoring the carbon released by clearing tropical forests for palm oil plantations.

They provided the quantitative basis for successive European directives. A UN Special Rapporteur called biofuel mandates “a crime against humanity”.

Cooking stoves

Indoor pollution from solid fuels kills an estimated 2.9 million people annually in the Global South.

Yet donors have refused to fund gas stoves on the grounds that they use fossil fuels.

The pathology is the same: a model that counts one variable (carbon emission) while rendering others invisible.

Two visions of planetary harm

Messy, local, attributable. Indoor and outdoor air pollution; plastic in the oceans; illegal dumpsites, hexavalent chromium; forever chemicals; eco-mafias; wars; Science is a driver of harm

Global, linear, unified. Greenhouse gas emissions gradually increase temperatures, leading to catastrophic events. Scientists defend the planet



The supply side of modelling

Vision 1 calls for many modest, local models — of a contaminated aquifer, a waste stream, **a reef system**, a fishery, an estuary

Vision 2 calls for integrated assessment models and digital twins, **an ocean-climate twin**. Computational ambition commands funding, prestige, and policy access

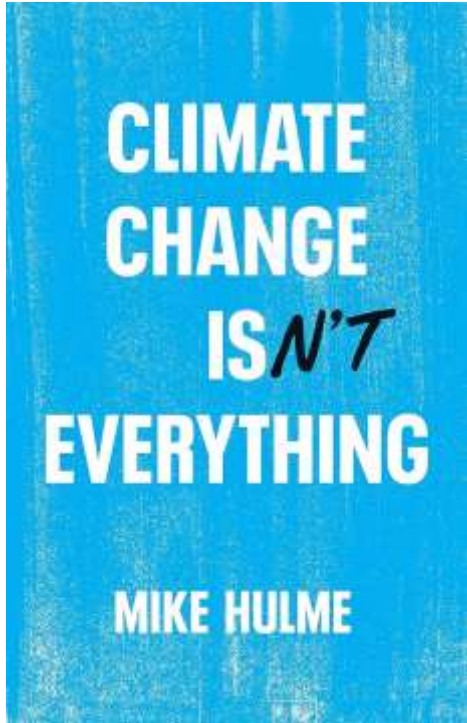
In the economy of modelling, scale itself becomes a source of epistemic authority



The future ‘climatized’

“Even though many other dimensions of change affecting human and ecological futures are inherently unpredictable — for example, technology, wars, pandemics, economic developments, religions, cultural values — by elevating a ‘predictable’ climate as the primary driver of change the future can nevertheless seemingly be made knowable. The future is thus ‘climatized’.”

Mike Hulme, climatologist



Climate change cannot be the lens through which to look at the world's problems. The war in Syria is not a result of climate change

Rejecting climatic determinism is not a refutation of climate change but of its instrumental use

[Home](#) > [Sustainability Science](#) > Article

The more things change, the more they stay the same: promises of bioeconomy and the economy of promises

Special Feature: Editorial | [Open Access](#) | Published: 23 March 2023 | 18, 557–568 (2023)

[Download PDF](#) 

 You have full access to this [open access](#) article



[Sustainability Science](#)

[Aims and scope](#) →

[Submit manuscript](#) →

[Dennis Eversberg](#) , [Philip Koch](#), [Rosa Lehmann](#), [Andrea Saltelli](#), [Sabaheta Ramcilovic-Suominen](#) & [Zora Kovacic](#)

2247 Accesses 5 Citations 7 Altmetric [Metrics](#) [Cite this article](#)

[Use our pre-submission checklist](#) →

Avoid common mistakes on your manuscript.



Part of a collection:

Economics of Techno-scientific Promises = The promise of ‘transformation without transformation’

Fantastic narratives of circular economy, geoengineering, rapid transitions & decarbonization just around the corner



Giuseppe Tomasi di Lampedusa
(1896–1957)

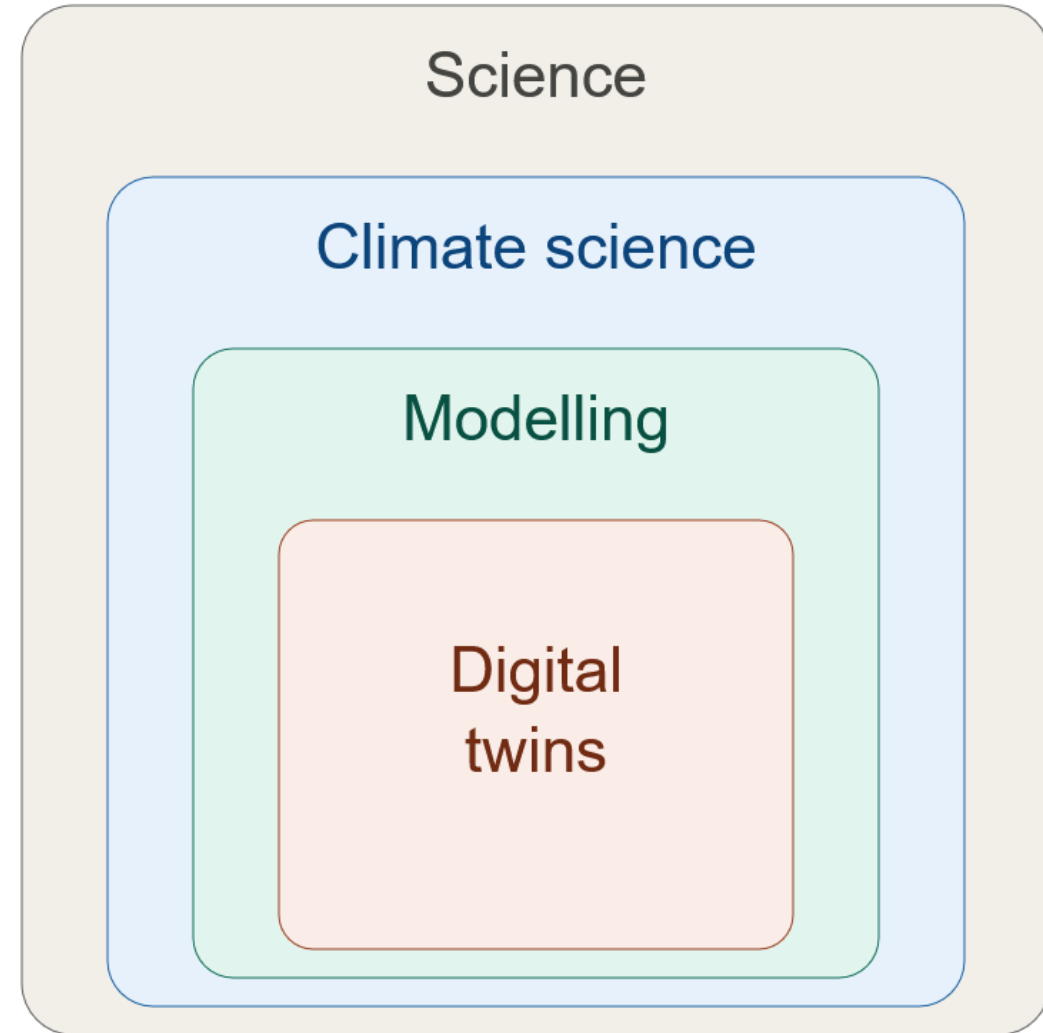


Migration of epistemic authority

The authority of science mediated through climate science

The authority of climate science mediated through modelling, and now the twins

➔ The credibility of science is inseparable from the credibility of the models that sustain it



Digital Twins of the Earth

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

- Margrethe Vestager -

"The launch of the initial Destination Earth (DestinE) is a true game changer in our fight against climate change," says Margrethe Vestager, Executive Vice-President for a Europe Fit for the Digital Age. "It means that we can observe environmental challenges which can help us **predict** future scenarios - like we have never done before... Today, the future is literally at our fingertips."

Margrethe Vestager



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!

DT's are marketed as a source of 'climate intelligence' but if it is true that "Financial markets and private companies, are in an "arms race" for climate intelligence" [*], should this race be met with public funds?

Rise of the Climate Rating Agencies

Government and the private sector rely increasingly on risk-modeling firms that claim they can zero in on exposure to climate change.

BY LEE HARRIS APRIL 12, 2023

2.4k
Shares



ILLUSTRATION BY ROB DOBI

[*] L. Harris, "Rise of the Climate Rating Agencies," *The American Prospect*, Apr. 12, 2023. Accessed: Jun. 07, 2023. [Online]. Available: <https://prospect.org/api/content/6015e258-d87d-11ed-bd1d-12163087a831/>

Part IV – Responsible modelling: what can you do?

Mind the assumptions

Assess uncertainty and sensitivity

Mind the hubris

Complexity can be the enemy of relevance

Mind the framing

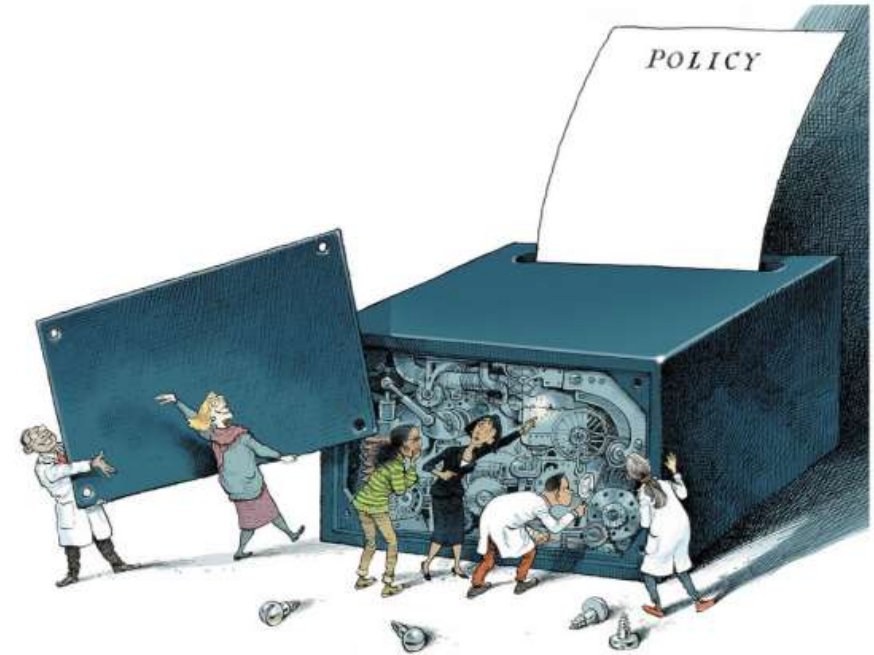
Match purpose and context

Mind the consequences

Quantification can backfire.

Mind the unknowns

Acknowledge ignorance



Know more about science, not more science

Citizens do not need to know more science, as much as they need to know more about science: its social nature, false starts, failures and disputes — “the way scientific facts are established”.

The decisive question for any model

“Whose problem does it frame, and what does it make thinkable or unthinkable for those who encounter it?”

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

PAUL R. EHRLICH AND JOHN P. HOLDREN [Authors Info & Affiliations](#)

Science

Open the process, not just the product

Wynne asked that *“the internal processes (and not just the products) of modeling projects [be] subject of public evaluation”*, because

“large-scale energy models are as much a symbolic medium for gaining policy access and influence for their authors as a direct method of producing ‘scientific’ inputs to policy”

Brian Wynne, 1984

www.andreasaltelli.eu



HOME

ABOUT ME

PUBLICATIONS

NEWS & VIDEOS

RESOURCES

Where to find this talk:



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 exception](#), [Seeking Cinderella](#), [Reformation](#)

Backup slides

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

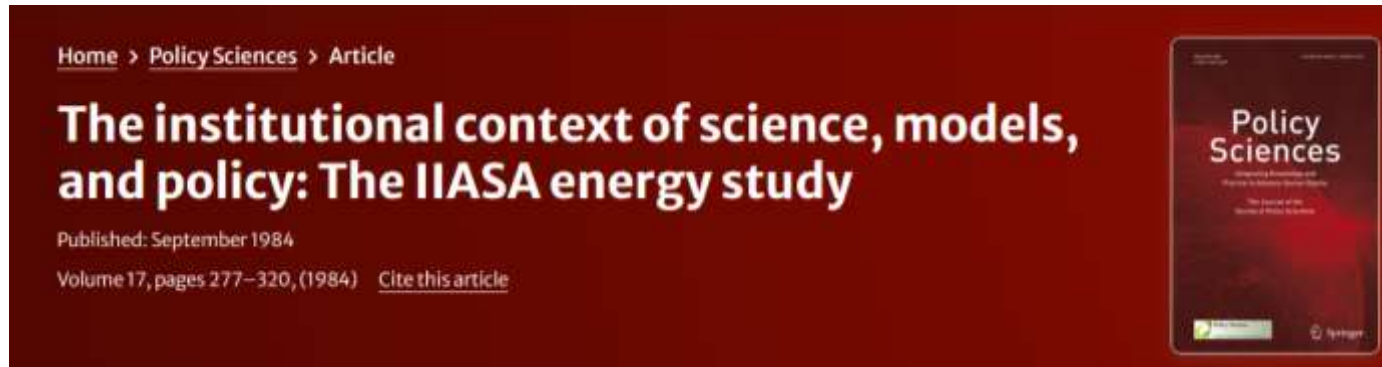
Consequences descending from state of exception

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 1.5°C
- What will be the cost of CO₂ averaged over the next three centuries

Then: the IIASA energy study (1981)



“models are more symbolic vehicles for gaining authority than objective technical frameworks”

(1984)

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 ...



See a summary here

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



Two visions of our impact on the planet

Messy and local

Plastic in the oceans, illegal dumpsites, PFAS, dioxins, eco-mafias: identifiable actors and responsibilities

→ many modest, local models: a contaminated aquifer, a waste stream, a polluted estuary

Global and linear

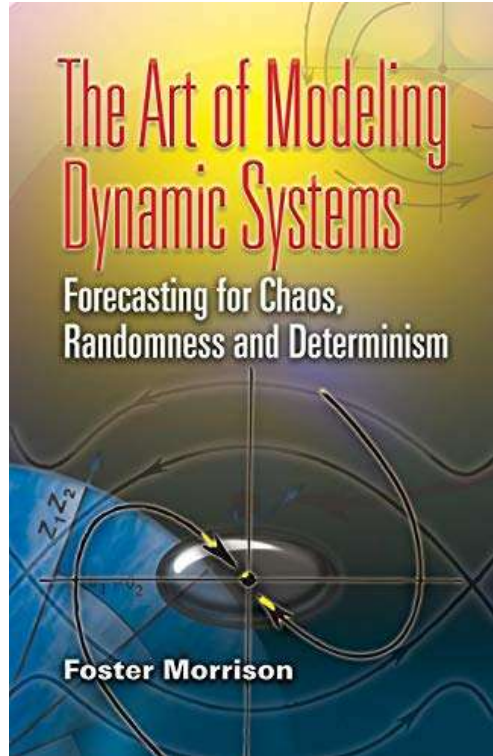
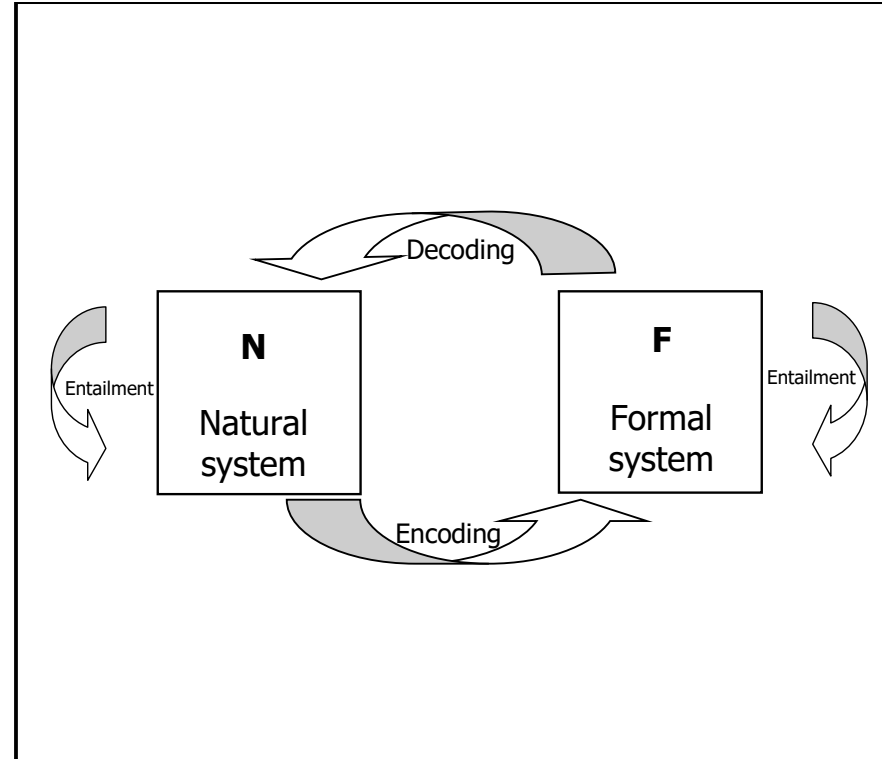
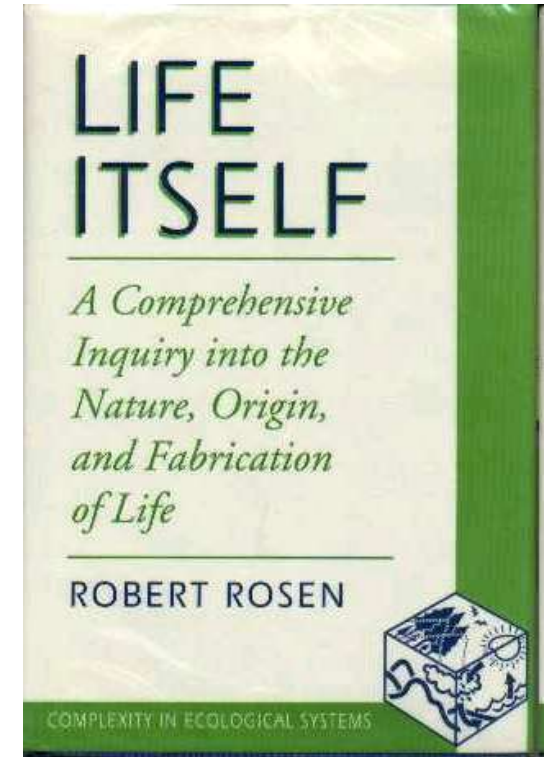
Greenhouse gas emissions gradually increase temperatures and lead to catastrophic events

→ vast integrated assessment models and digital twins of the Earth

“In the economy of modelling, scale itself becomes a source of epistemic authority, independent of explanatory power or practical usefulness.”

Why models live in a state of exception

Lack of agreed standards. Modelling as art/craft (Rosen).



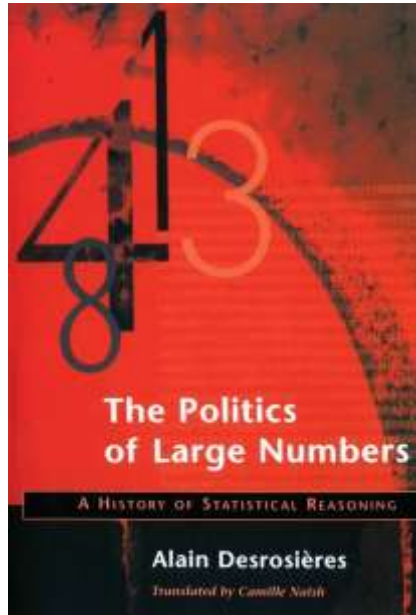
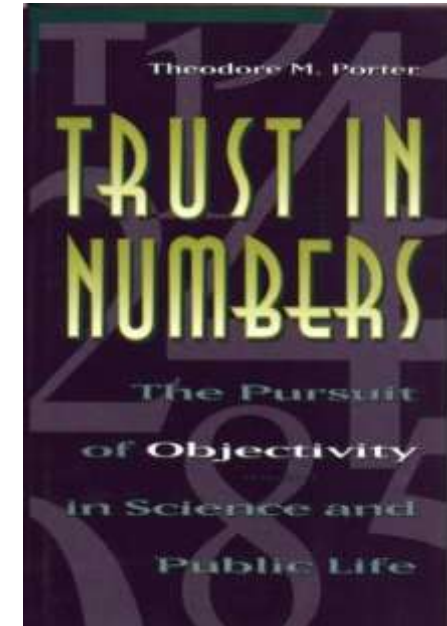
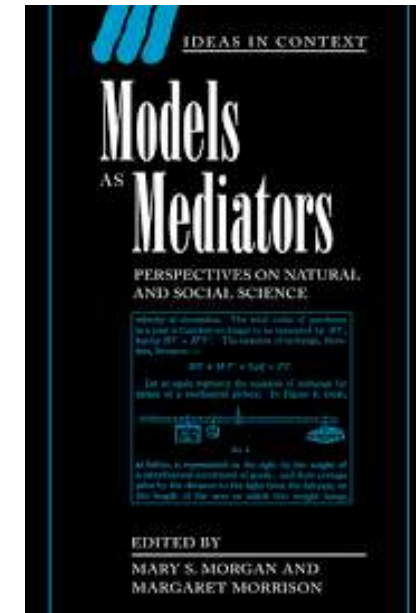
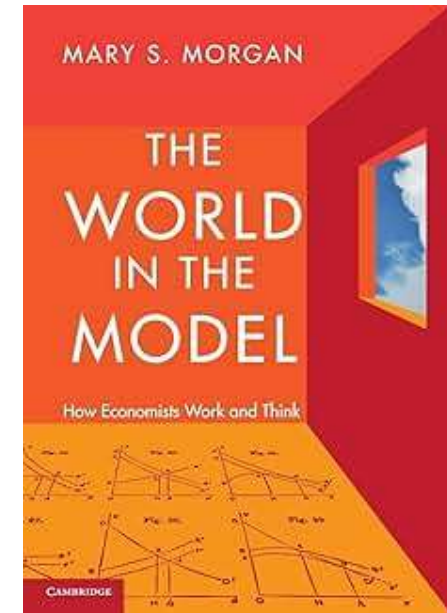
Louie, A.H. 2010. “Robert Rosen’s Anticipatory Systems.” *Foresight* 12 (3): 18–29.

Padilla, J. J., Diallo, S. Y., Lynch, C. J., & Gore, R. (2018). Observations on the practice and profession of modeling and simulation: A survey approach. *SIMULATION*, 94(6), 493–506.

Why models live in a state of exception

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).



Models have a better pretence to neutrality than other instances of quantification

BUT: A technical proof of quality is illusory without a parallel investigation of normative quality; the example of indicators of employment

Technical Quality

Normative quality

Justice: Means versus Freedoms

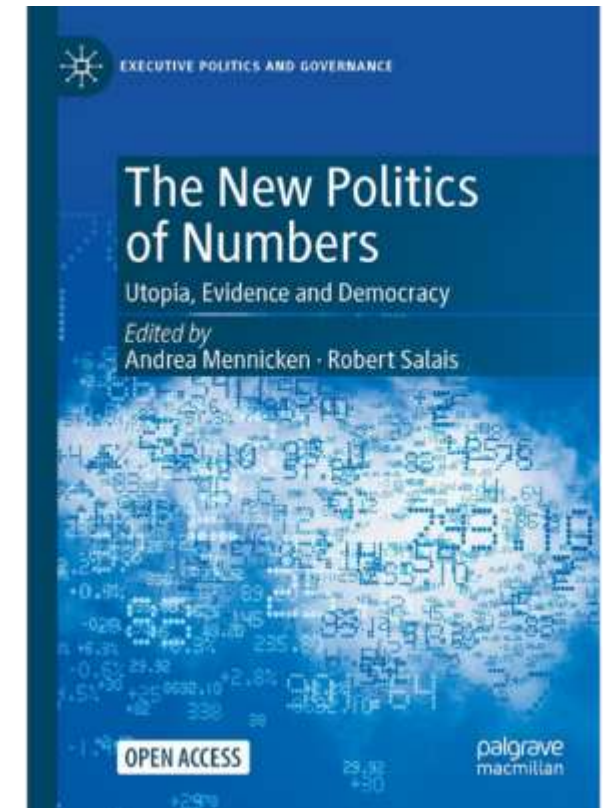
Author(s): Amartya Sen

Source: *Philosophy & Public Affairs*, Vol. 19, No. 2 (Spring, 1990), pp. 111-121

Published by: [Wiley](#)

Stable URL: <http://www.jstor.org/stable/2265406>

Accessed: 28/10/2014 14:48



Salais, R. (2022). “La donnée n’est pas un donné”: Statistics, Quantification and Democratic Choice. In *The New Politics of Numbers: Utopia, Evidence and Democracy*, Andrea Mennicken and Robert Salais, Palgrave Macmillan, pp. 379–415.



Why models live in a state of exception

Mathematical models are extremely malleable

Models lend themselves very naturally to evidence based policy. In statistics you have to reverse the statistical pyramid to achieve the same result – this goes much faster with models

Evidence based policy	Statistics (creating things that hold together for the solution of practical problems)
Policy based evidence	Governance driven quantification (a reversal of the statistical pyramid)

Models are fragile

“... 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’



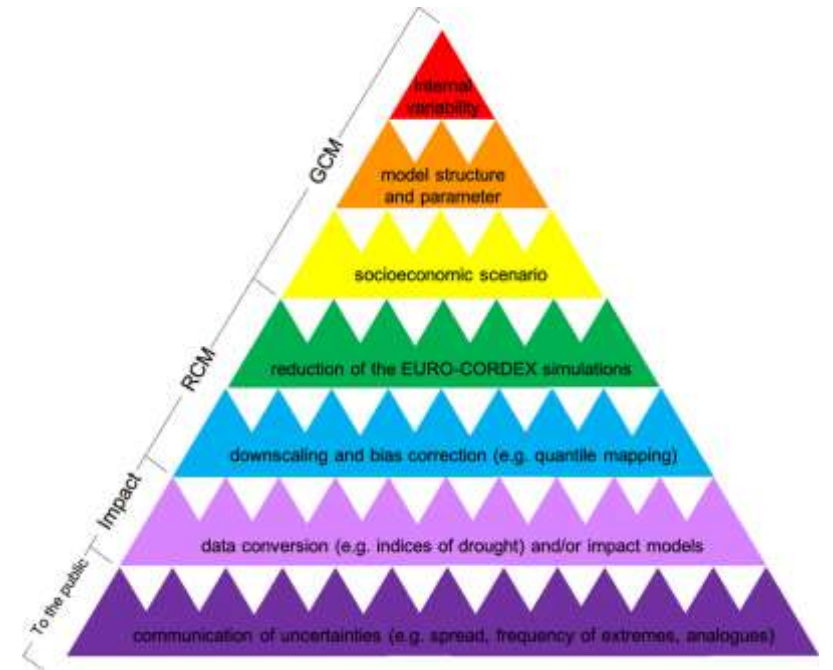
[1] S. C. Fletcher, ‘The Principle of Stability’, *Philosopher’s Imprint*, vol. 20, no. 3, 2020, Accessed: Sep. 08, 2024. [Online].

Why models live in a state of exception

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.

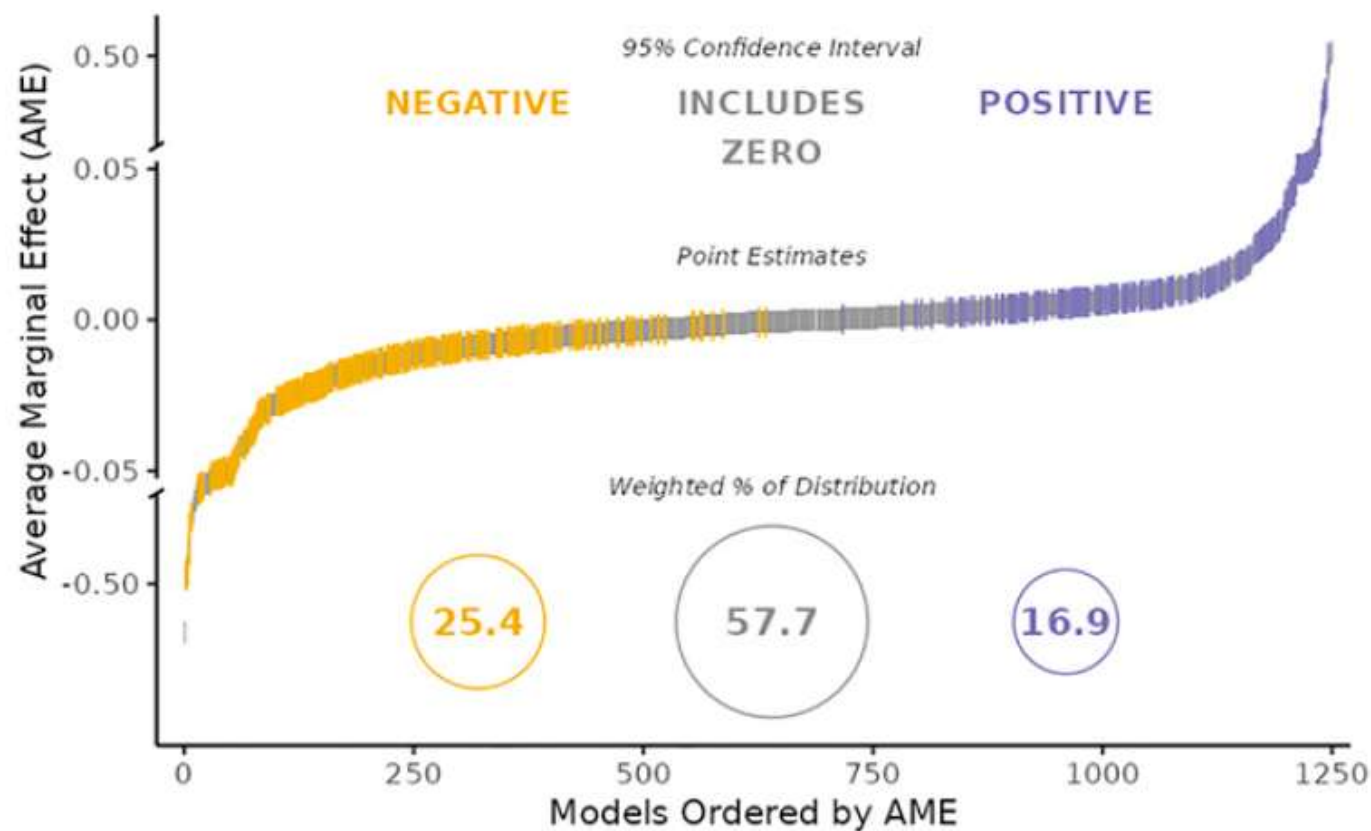


Why models live in a state of exception

Models are fragile

And still one is
surprised to
find this out





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

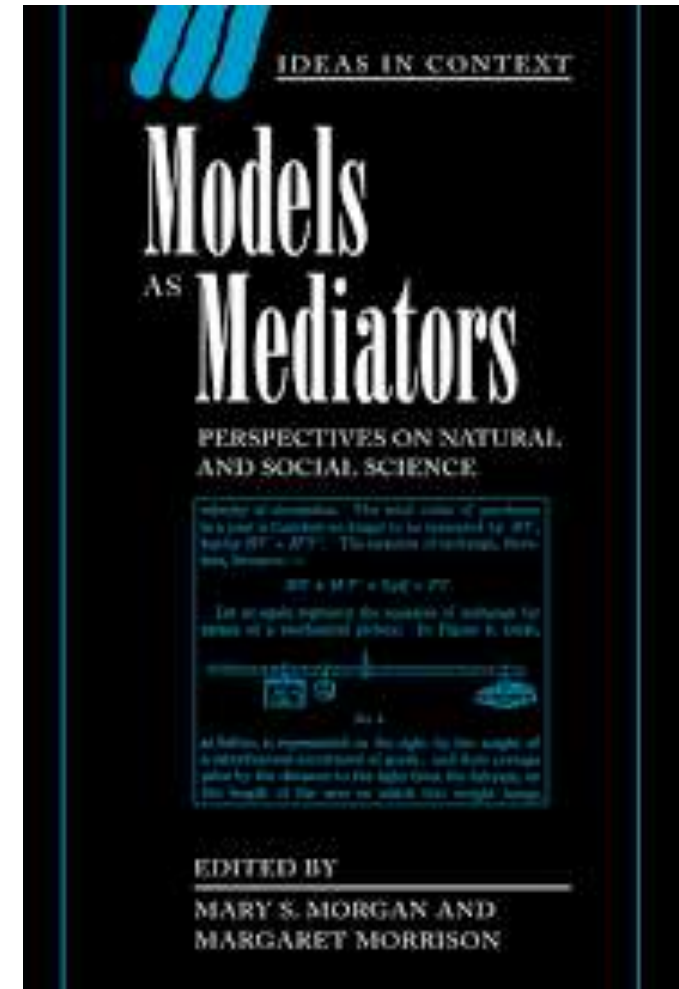
AUTHORS

[Andrea Saltelli](#), Arnald Puy, Alessio Lachi, and [Nate Breznau](#)

Why models live in a state of exception

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).

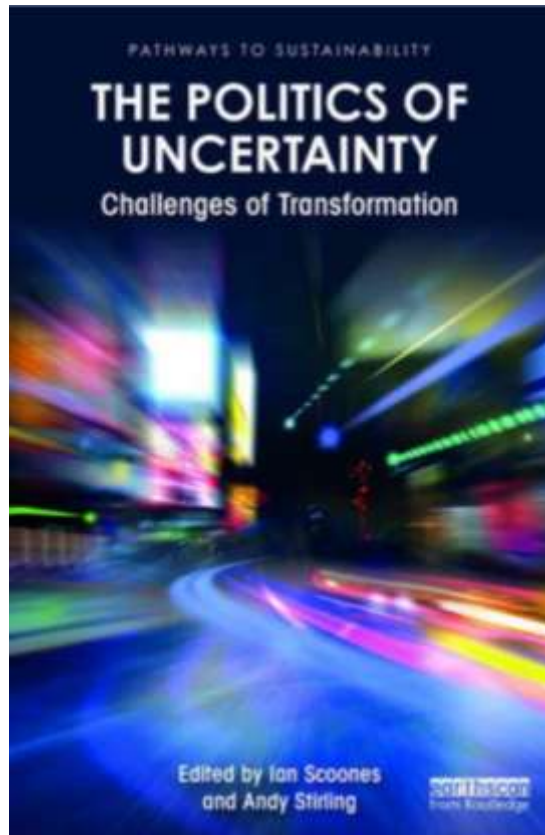


Consequences descending from state of exception

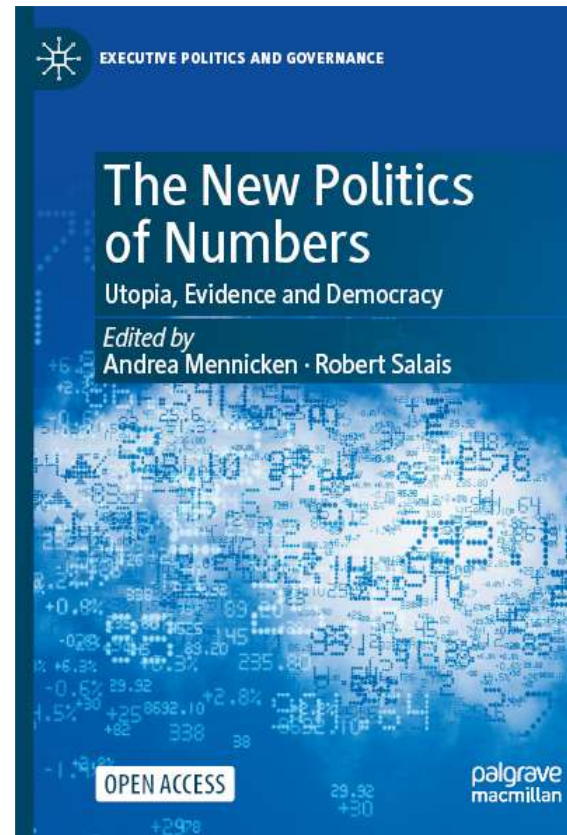
Gross asymmetry developers/ users

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.

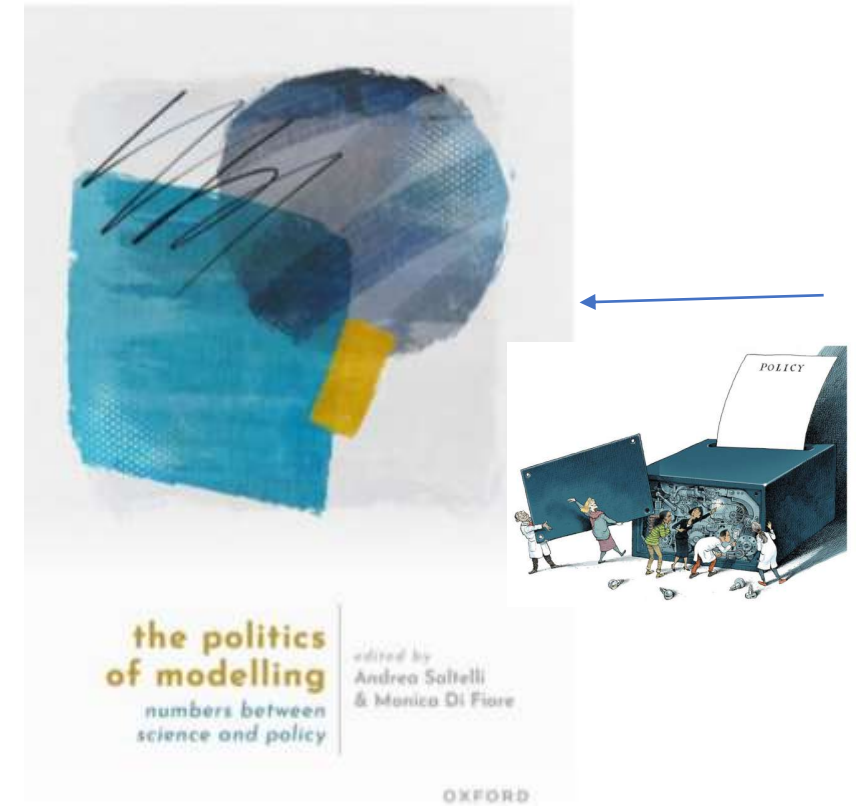




2020



2022



2023

Reveal the policy of the numbers

Consequences descending from state of exception

Models and trans-science

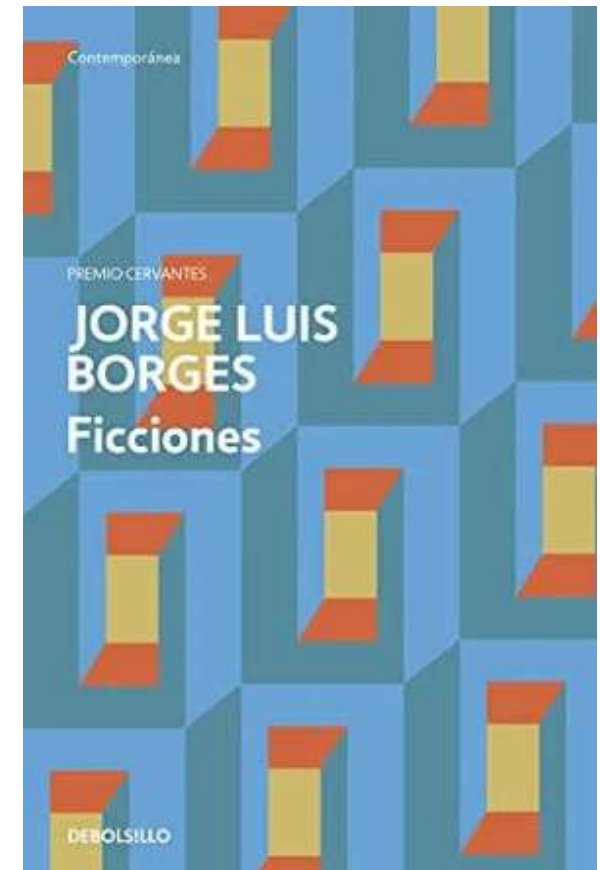
Model as Jorge Luis Borges' (1946) one-to-one map of the empire

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.



A digital twin of Earth for the green transition

For its green transition, the EU plans to fund the development of digital twins of Earth. For these twins to be more than big data atlases, they must create a qualitatively new Earth system simulation and observation capability using a methodological framework responsible for exceptional advances in numerical weather prediction.

Peter Bauer, Bjorn Stevens and Wilco Hazeleger

The European Union (EU) intends to become climate neutral by 2050, and the set of policies designed to bring about this green transition — the European Green Deal — was announced in December 2019 (ref. 1). Accompanied by €1 trillion of planned investment, Green Deal policies aim to help the world's second-largest economy sustainably produce energy, develop carbon-neutral fuels and advance circular products in energy-intensive industrial sectors with zero waste and zero pollution.

A key element of the Green Deal is its dependence on the 'digital transformation' — an openly accessible and interoperable European dataspace as a central hub for informed decision making. The EU identified two landmark actions to support the necessary information systems: GreenData4All² and Destination Earth³. Whereas GreenData4All will develop the European approach to discover, manage and exploit geospatial information, Destination Earth aims to construct highly accurate models, or 'digital twins', of the Earth to monitor and predict environmental change and human impact in support of sustainable development. Aligned with the new Digital Europe funding programme⁴, Destination Earth is expected to start in 2021, and the first, high-priority digital twins serving extremes prediction and climate change adaptation will



Credit: Map of Layerace / Freepik

Digital Twins of the Earth - in the EU Destination Earth

[nature](#) > [nature reviews earth & environment](#) > [review articles](#) > [article](#)

Review Article | [Published: 02 May 2023](#)

Big Data in Earth system science and progress towards a digital twin

[Xin Li](#) , [Min Feng](#) , [Youhua Ran](#), [Yang Su](#), [Feng Liu](#), [Chunlin Huang](#), [Huanfeng Shen](#), [Qing Xiao](#), [Jianbin Su](#), [Shiwei Yuan](#) & [Huadong Guo](#)

Nature Reviews Earth & Environment **4**, 319–332 (2023) | [Cite this article](#)

3576 Accesses | 3 Citations | 27 Altmetric | [Metrics](#)

 Cornell University

 arXiv > physics > arXiv:2306.11175

We gratefully acknowledge su

Search...

Help | Adva

Physics > Physics and Society

[Submitted on 19 Jun 2023]

Developing Digital Twins for Earth Systems: Purpose, Requisites, and Benefits

Yuhao Rao, Rob Redmon, Kirstine Dale, Sue E. Haupt, Aaron Hopkinson, Ann Bostrom, Sid Boukabara, Thomas Geenen, David M. Hall, Benjamin D. Smith, Dev Niyogi, V. Ramaswamy, Eric A. Kihn

The accelerated change in our planet due to human activities has led to grand societal challenges including health crises, intensified extreme weather events, food security, environmental injustice, etc. Digital twin systems combined with emerging technologies such as artificial intelligence and edge computing provide opportunities to support planning and decision-making to address these challenges. Digital twins for Earth systems (DT4ESs) are defined as the digital representation of the complex integrated Earth system including both natural processes and human activities. They have the potential to enable a diverse range of users to explore what-if scenarios across spatial and temporal scales to improve our understanding, prediction, mitigation, and adaptation to grand societal challenges. The 4th NOAA AI Workshop convened around 100 members who are developing or interested in participating in the development of DT4ES to discuss a shared community vision and path forward on fostering a future ecosystem of interoperable DT4ES. This paper summarizes the workshop discussions around DT4ES. We first defined the foundational features of a viable digital twins for Earth system that can be used to guide the development of various use cases of DT4ES. Finally, we made practical recommendations for the community on different aspects of collaboration in order to enable a future ecosystem of interoperable DT4ES, including equity-centered use case development, community-driven investigation of interoperability for DT4ES, trust-oriented co-development, and developing a community of practice.

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



By [Rosie Frost](#) & [Angela Symons](#)

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



[Share this article](#)



[Comments](#)

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

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

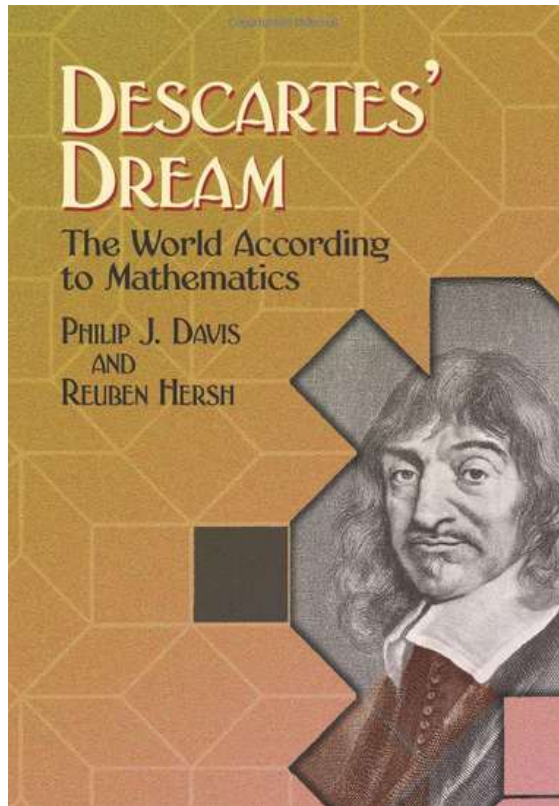
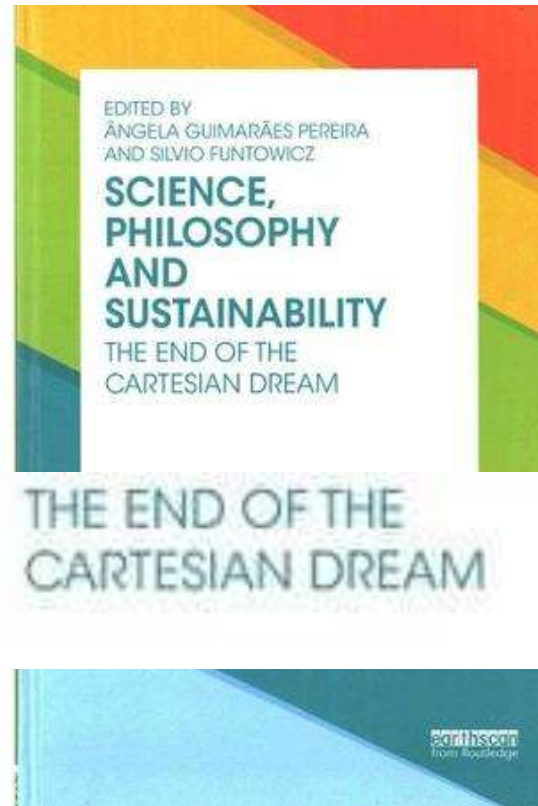
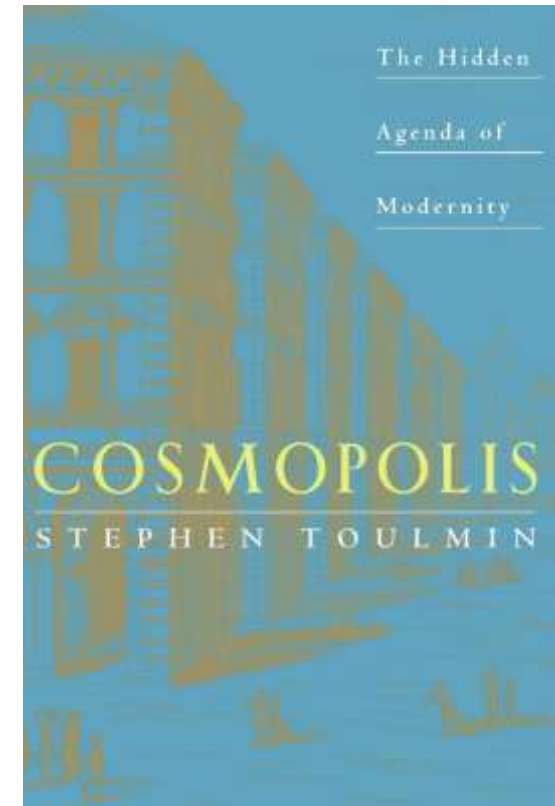
YOU CONTROL CLIMATE CHANGE.



www.climatechange.eu.com

TURN DOWN. SWITCH OFF. RECYCLE. WALK. **CHANGE**

Digital Twins: The planet as a manufact; the ultimate Cartesian Dream

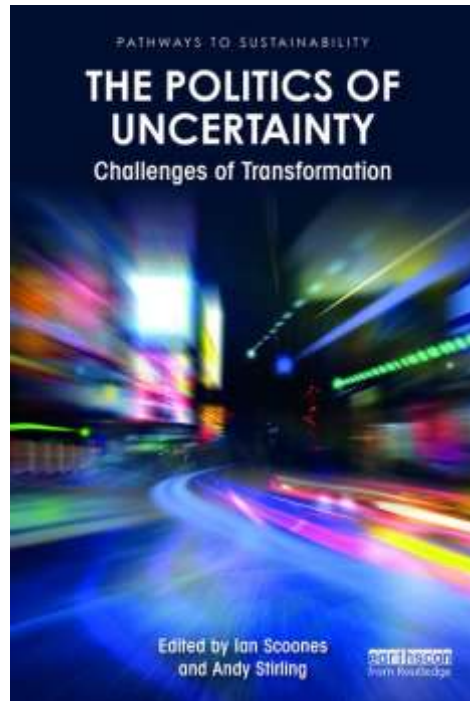


Problems with DestinE: A-la-Zuckerberg approach to introducing new technologies: first it is done, then one worries about “How to embed the ethical, legal, and social considerations in the Digital Twin of the Earth and its interface, such as privacy, equity, accessibility ...”



Problems with DestinE

The EC leans toward technology as a conduit to solve policy problems → European institutions are vulnerable to projects oriented to technological solutions and technological optimism



4

THE UNRAVELLING OF TECHNOCRATIC ORTHODOXY?

Contemporary knowledge politics
in technology regulation

Patrick van Zwanenberg

“... researchers might be led by their quest for funds to promote “digital twins” of everything—DTs of biodiversity (BioDT) and of extreme events (DT-GEO) are already in progress—thus overstretching the metaphor ...

↓
...we note that societal concern with pollinator decline is attentive to phenomena of regulatory capture, seen as one of the causes of pesticide-friendly legislation” →
(not in BioDT)



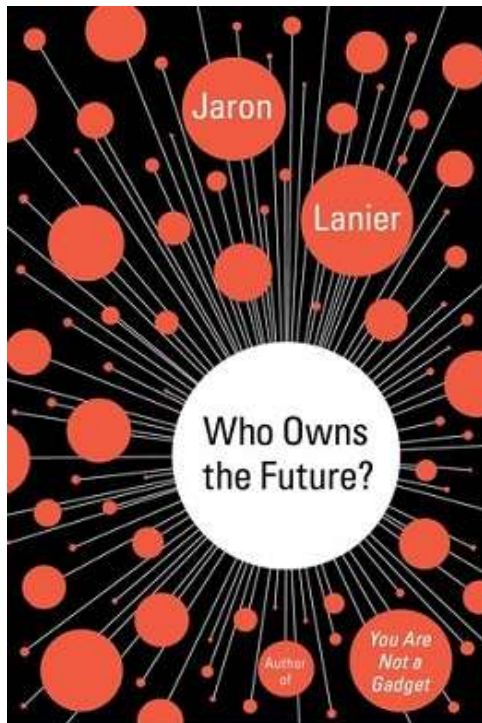
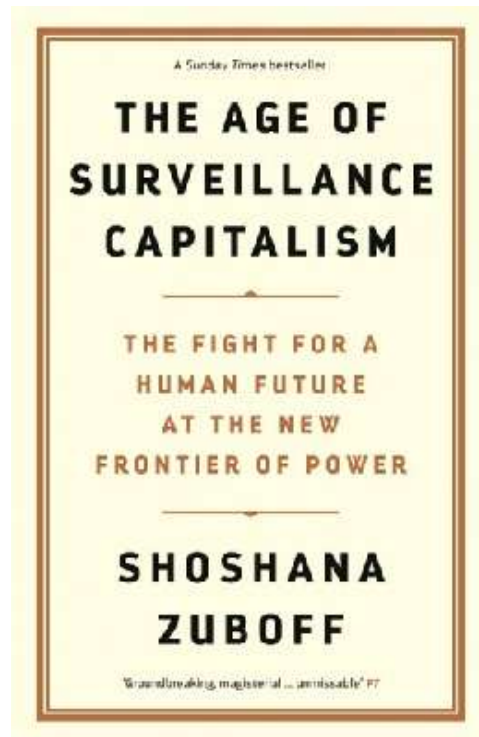
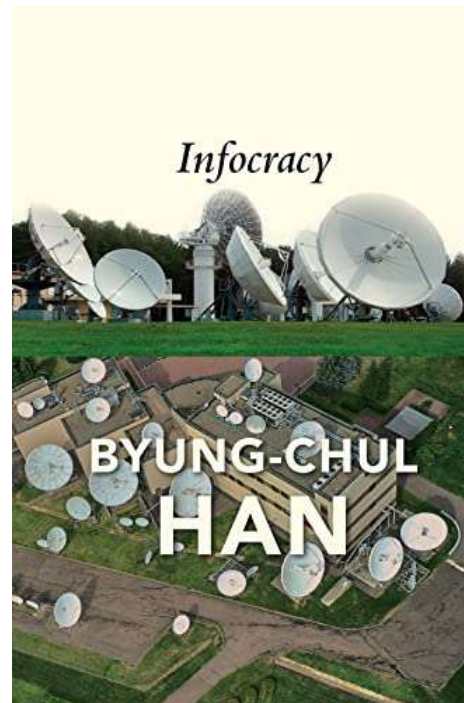
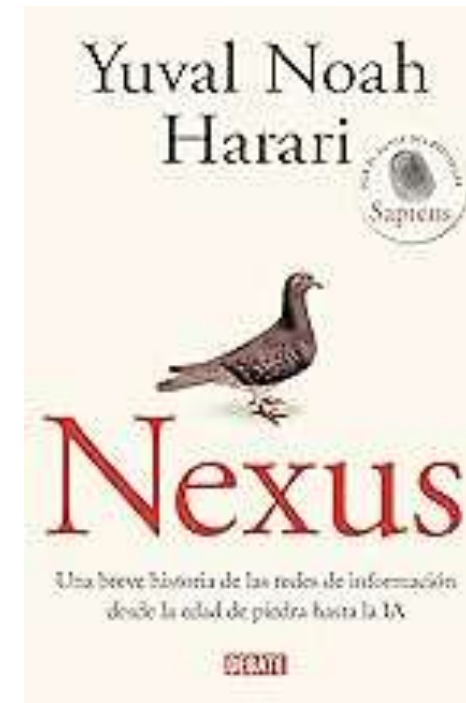
Destination Earth's nature-based metaphors: “Digital ecosystems”, “evolutionary development”, “data lakes” and “digital species” … and yet we will need AI to read the output of Digital Twins (Bauer et al, 2024)



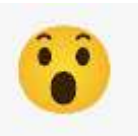
Bauer, Peter, Torsten Hoefler, Bjorn Stevens, and Wilco Hazeleger. 2024. ‘Digital Twins of Earth and the Computing Challenge of Human Interaction’. *Nature Computational Science* 4 (3): 154–57. <https://doi.org/10.1038/s43588-024-00599-3>.

Problems with DestinE

The epistemic community around DestinE unexposed to the concerns about the digitalization of the real



Harari
quoque



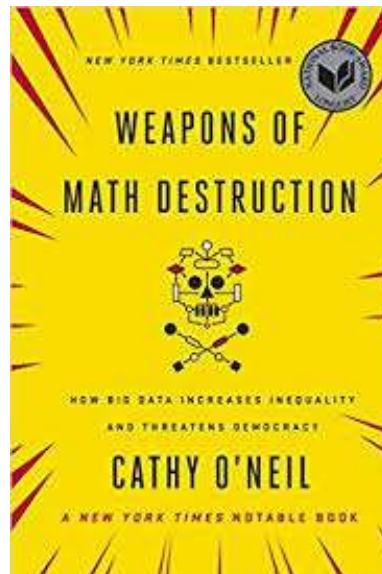
...

Powered by algorithms, governance by (visible and invisible) numbers contributes to a loss of democratic agency (a-democracy for Salais, fascism for Mc Quillan, refeudalization for Supiot...)

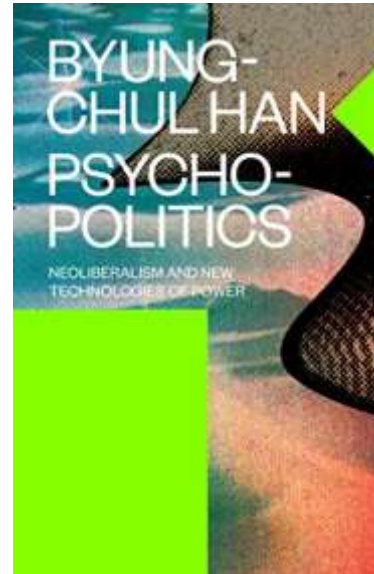
2015
(jurist)



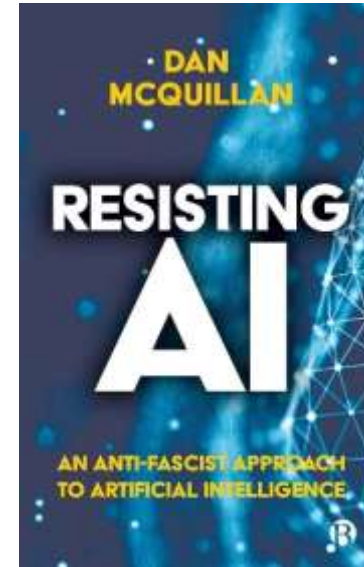
2016
(data scientist)



2017
(philosopher)



2022
(physicist/sociologist)



The Coming Tech Autocracy

Sue Halpern
November 7, 2024 issue

A functional government, committed to safeguarding its citizens, might be keen to create a regulatory agency for AI or pass comprehensive legislation, but we in the United States do not have such a government.

One new book on this
topic every second day

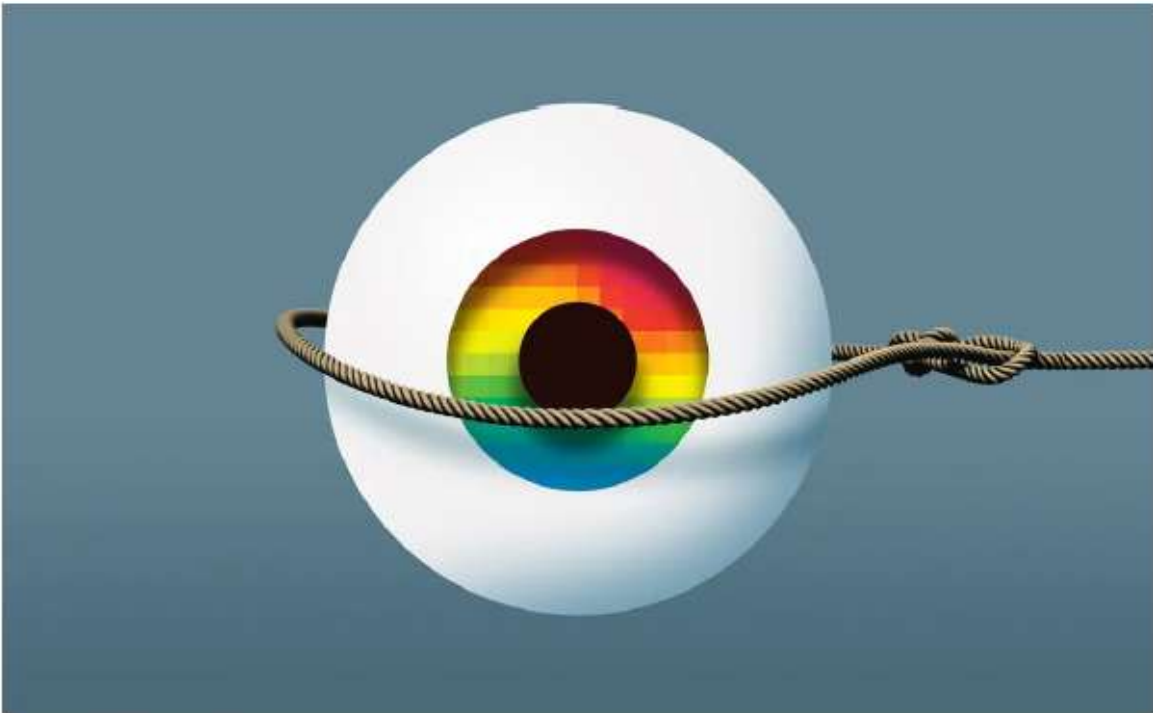


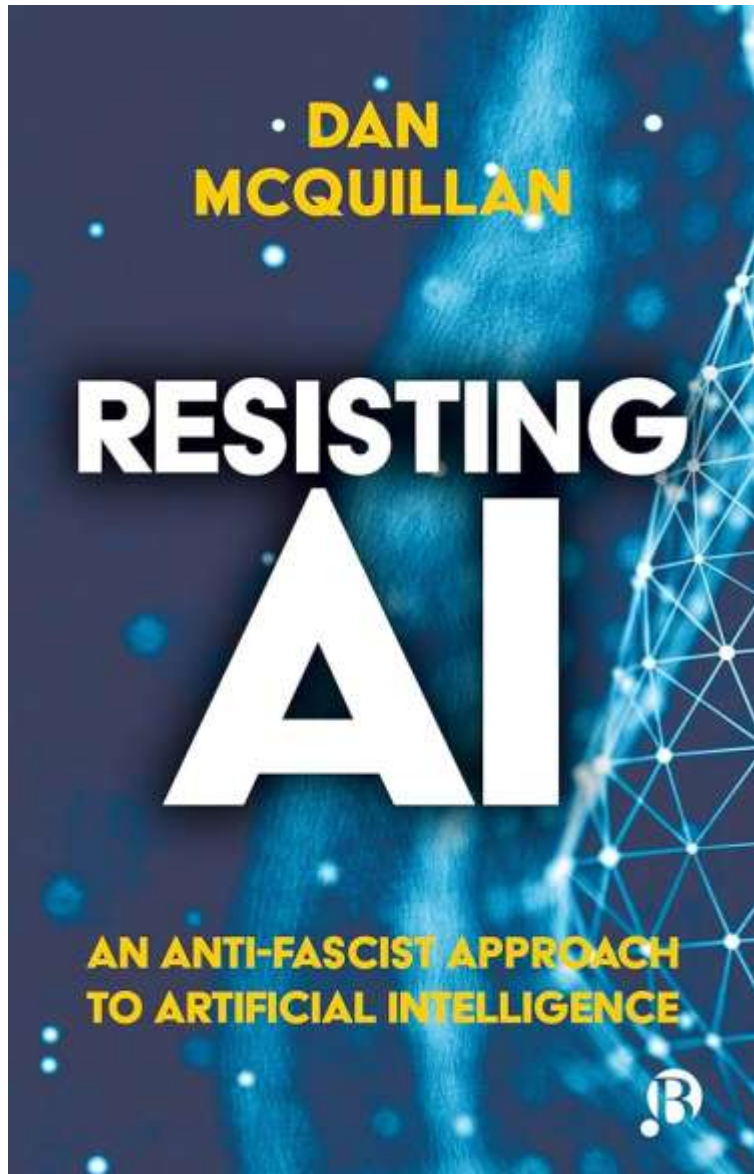
Illustration by Matt Dorfman

AI Needs You: How We Can Change AI's Future and Save Our Own
by Verity Harding

Taming Silicon Valley: How We Can Ensure That AI Works for Us
by Gary Marcus

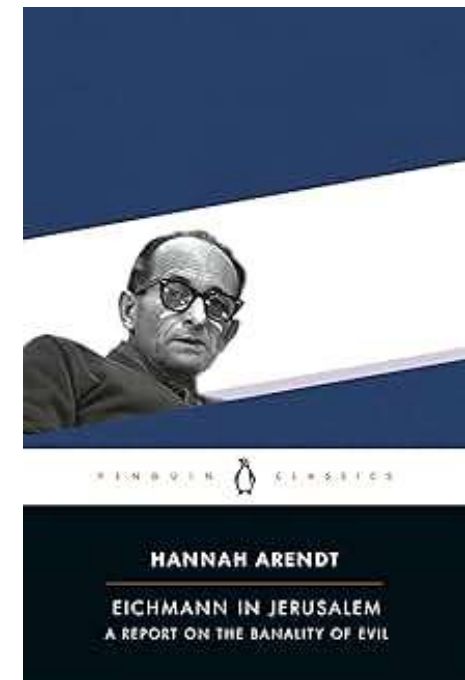
The Mind's Mirror: Risk and Reward in the Age of AI
by Daniela Rus and Gregory Mone

Code Dependent: Living in the Shadow of AI
by Madhumita Murgia



AI may as a continuation and reinforcement of bureaucratic forms of discrimination and violence, ultimately fostering authoritarian outcomes; an ‘impersonal Eichmann’

AI's promise of objective calculability is antithetical to an egalitarian and just society



[Home](#) > [Sustainability Science](#) > Article

The more things change, the more they stay the same: promises of bioeconomy and the economy of promises

Special Feature: Editorial | [Open Access](#) | Published: 23 March 2023 | 18,557–568 (2023)[Download PDF](#) ✔ You have full access to this [open access](#) article[Sustainability Science](#)[Aims and scope](#) →[Submit manuscript](#) →[Dennis Eversberg](#) , [Philip Koch](#), [Rosa Lehmann](#), [Andrea Saltelli](#), [Sabaheta Ramcilovic-Suominen](#) & [Zora Kovacic](#)[2247 Accesses](#) [5 Citations](#) [7 Altmetric](#) [Metrics](#) [Cite this article](#)[Use our pre-submission checklist](#) →

Avoid common mistakes on your manuscript.



Part of a collection:

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'

Consequences descending from state of exception

Have the strongest grip in 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.

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

...



Solutions to resolve the state of exception: adopt more lenses

Environmental Science and Policy 142 (2023) 99–111



Contents lists available at [ScienceDirect](#)

Environmental Science and Policy

journal homepage: www.elsevier.com/locate/envsci



Impact assessment culture in the European Union. Time for something new?

Andrea Saltelli^{a,b,*}, Marta Kuc-Czarnecka^c, Samuele Lo Piano^d, Máté János Lőrincz^d,
Magdalena Olczyk^c, Arnald Puy^e, Erik Reinert^{f,g}, Stefán Thor Smith^d,
Jeroen P. van der Sluijs^{b,h}

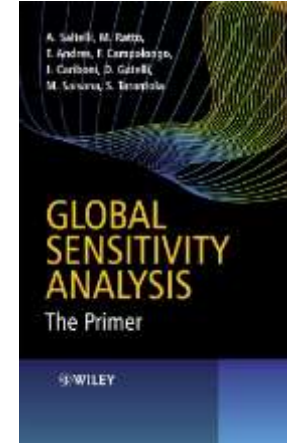
Proposed lenses

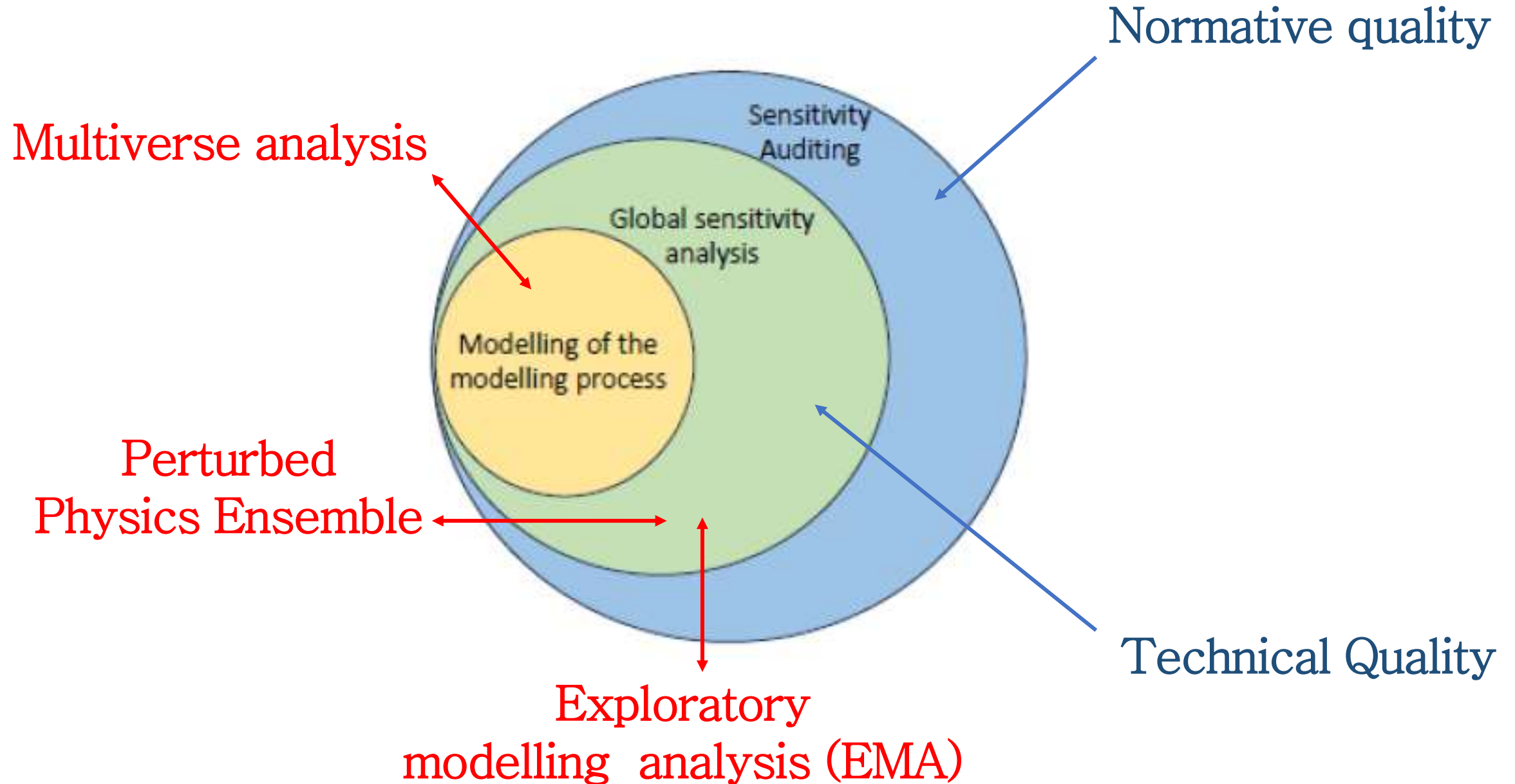
- Non-Ricardian economics
- Bioeconomics (in the sense of Nicholas Georgescu-Roegen)
- Approaches originated in the context of post-normal science
 - global uncertainty and sensitivity analysis
 - sensitivity auditing
 - NUSAP
 - quantitative storytelling



Impact assessment culture in the European Union. Time for something new?

Andrea Saltelli^{a,b,e}, Marta Kuc-Czarnecka^c, Samuele Lo Piano^d, Máté János Lőrincz^d, Magdalena Olczyk^c, Arnald Puy^e, Erik Reinert^{f,g}, Stefán Thor Smith^d, Jeroen P. van der Sluijs^{b,h}





Solutions to resolve the state of exception

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?



WILEY Online Library

COMMENTARY

 Open Access



What did COVID-19 really teach us about science, evidence and society?

Andrea Saltelli , Joachim P. Sturmberg, Daniel Sarewitz, John P. A. Ioannidis

First published: 06 June 2023 | <https://doi.org/10.1111/jep.13876>

Could climate intelligence backfire? Consider the effects of mortgage securitization on the the last housing bubble recession started in 2007

Performing Climate Risks to Financial Stability

Are climate change models the source of our next financial crisis?

MAY 17, 2024

PRINT

SHARE



As the dust of the global financial crisis of 2007–08 settled, many of those looking for someone to blame for the economic disaster zeroed in on something called the Gaussian copula model, a family of mathematical functions used to estimate the probability distribution of investment losses. In a [lament](#) on Wired, for example, the journalist Felix Salmon wrote that the model had become “so deeply entrenched—and was making people so much money—that warnings about



Jessica Weinkle

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

[Add languages](#) ▼

[Article](#) [Talk](#)

[Read](#) [Edit](#) [View history](#) [☆](#) [Tools](#) ▼

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.

Don't forget 2013 EC's Human Brain Project

“the European Commission awarded ... a staggering 1 billion euro grant ... the people I contacted struggled to name a major contribution that the HBP has made in the past decade” (Yong, 2019)

nature

[Explore content](#) ▾ [About the journal](#) ▾ [Publish with us](#) ▾

[nature](#) > [comment](#) > article

[Published: 03 September 2014](#)

Neuroscience: Where is the brain in the Human Brain Project?

[Yves Frégnac](#) ✉ & [Gilles Laurent](#) ✉

[Nature](#) **513**, 27–29 (2014) | [Cite this article](#)

Newsletters

The Atlantic

SCIENCE

The Human Brain Project Hasn't Lived Up to Its Promise

Ten years ago, a neuroscientist said that within a decade he could simulate a human brain. Spoiler: It didn't happen.

By Ed Yong JULY 22, 2019

DT's assumes that climate change needs more evidence to promote political agency, and that said evidence comes in the form of DT's

riskthinking.AI

PRODUCTSPARTNERSABOUTRESOURCESaskRISKTHINKINGCONTACT USCAREERS

OUR CLIMATE DIGITAL TWIN (CDT)

A data and analytics platform,



COMPANY DATA

- Global Coverage (G40)
- 13,000 Parent Companies
- Linked to 80,000 Subsidiaries
- Tagged to 5 Million Asset Locations
- Monthly Updates

DERIVED CLIMATE DATA

- Forward-looking
- Stochastic
- Various Exposure Scores
- Projected to 2100
- History to 1850

MULTIFACTOR SCENARIOS

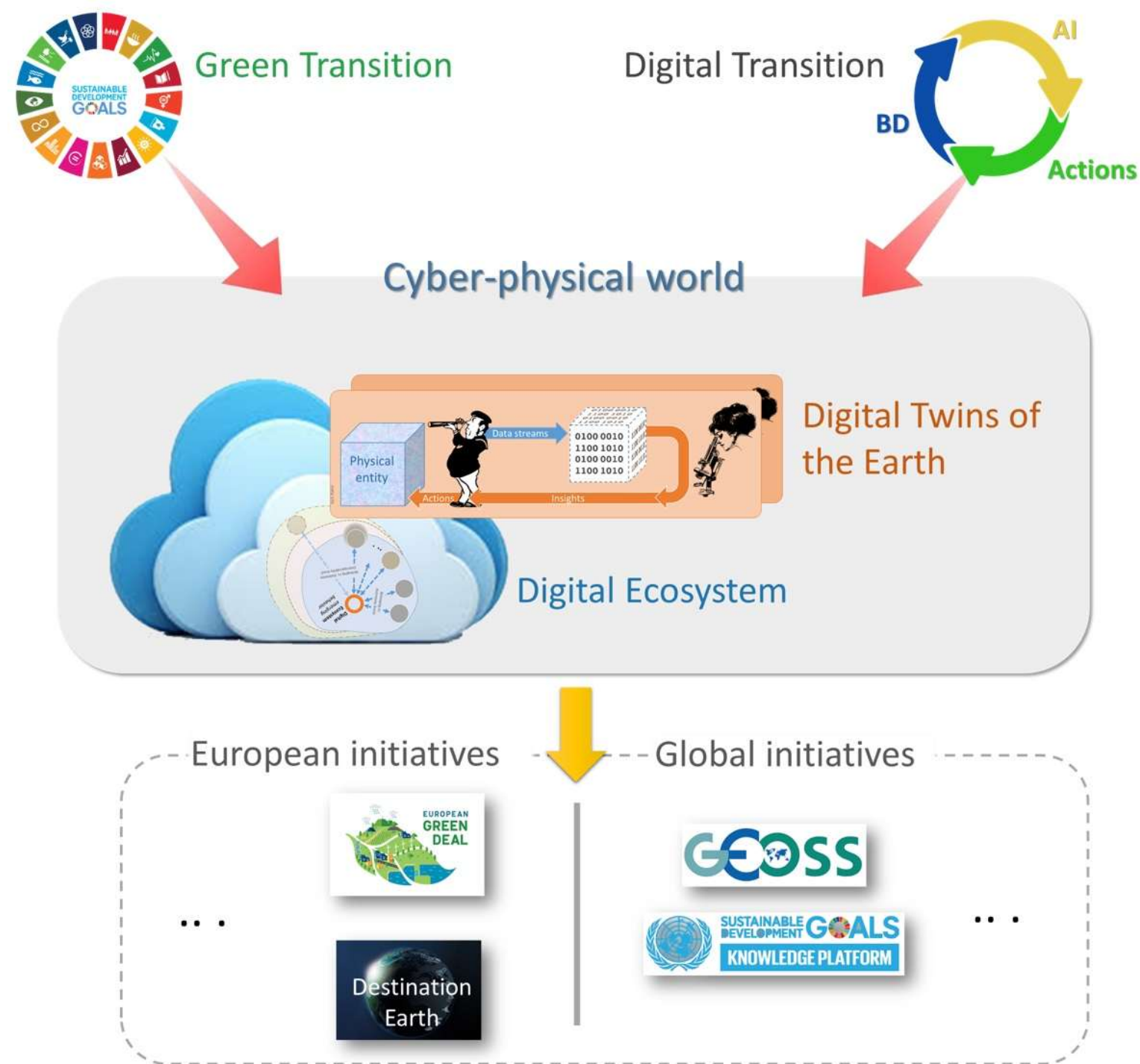
- Patented Methodology
- 16 Billion Simulations
- Spanning Set
- Physical Hazards
- Transition Data

AVAILABLE PRODUCTS

- Geospatial Asset Data Worldwide
- Geospatial Climate Hazard Data
- Company & Asset Climate Scores
- Upload & Merge Custom Data
- Option to Deploy Platform On-Site

[...] with the advent of the Digital Transformation, the interconnection between the physical and the digital world has become almost complete: economic, industrial, and social relationships have been moved to the “cyber-physical” world ...

Source: S. Nativi, P. Mazzetti, and M. Craglia, ‘Digital Ecosystems for Developing Digital Twins of the Earth: The Destination Earth Case’, Remote Sensing, vol. 13, no. 11, Art. no. 11, Jan. 2021, doi: 10.3390/rs13112119



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



Culture Unbound
Journal of Current Cultural Research

Funny Numbers

By Theodore M. Porter



COMMENTARY

Open Access



What did COVID-19 really teach us about science, evidence and society?

Andrea Saltelli Joachim P. Sturmberg, Daniel Sarewitz, John P. A. Ioannidis

First published: 06 June 2023 | <https://doi.org/10.1111/jep.13876>

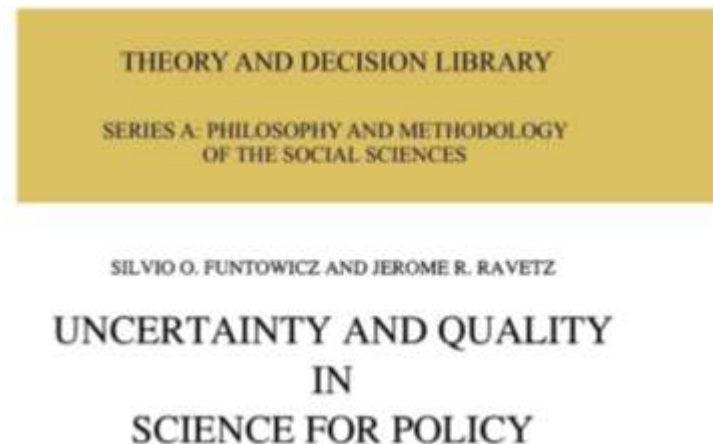
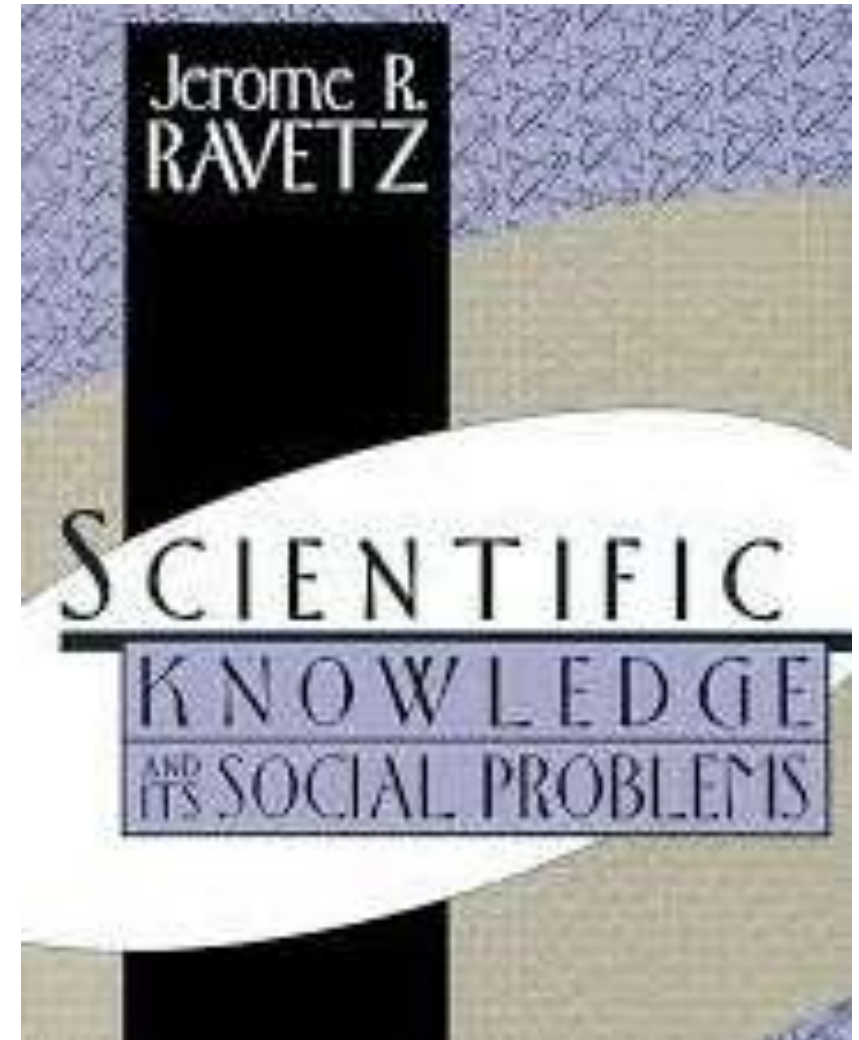
“COVID–19 policies allocated sacrifice, privation and suffering across all walks of society [but] radically different responses from nation to nation—from draconian lockdowns, to relatively permissive and flexible pandemic regimes—made obvious to all that the value of **scientific evidence** was to support 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.



Problems with DestinE

The engagement of social science and humanities that gets accepted in journals seems to be of a confirmatory nature – to help the actors of DestinE to receive societal consensus

For example:

Purportedly this is a critique but
... a rather sedated one



communications earth & environment

[Explore content](#) ▾ [About the journal](#) ▾ [Publish with us](#) ▾

[nature](#) > [communications earth & environment](#) > [perspectives](#) > [article](#)

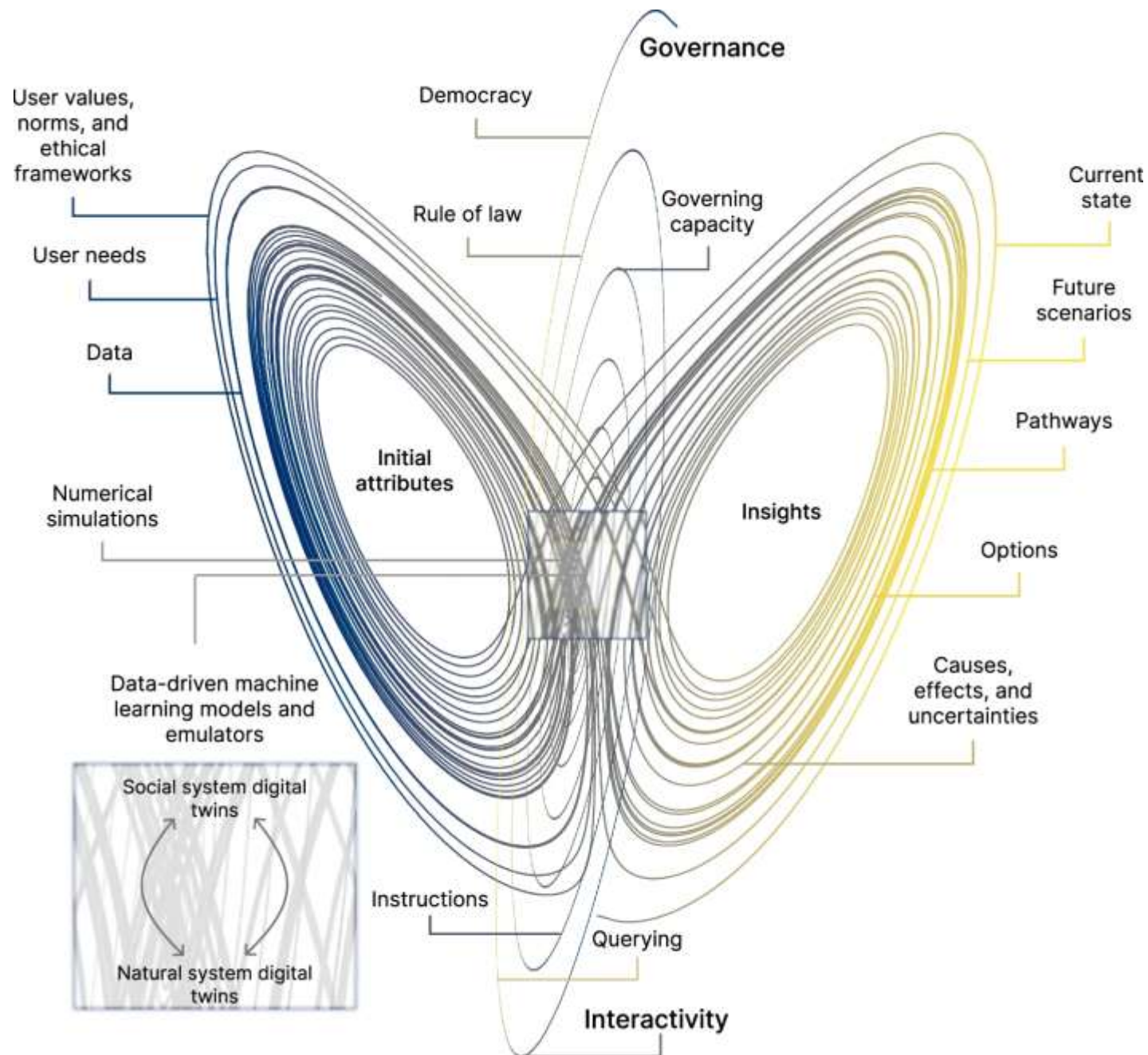
Perspective | [Open access](#) | Published: 27 August 2024

Digital twins of the Earth with and for humans

[W. Hazeleger](#) , [J. P. M. Aerts](#), [P. Bauer](#), [M. F. P. Bierkens](#), [G. Camps-Valls](#), [M. M. Dekker](#), [F. J. Doblas-Reyes](#), [V. Eyring](#), [C. Finkenauer](#), [A. Grundner](#), [S. Hachinger](#), [D. M. Hall](#), [T. Hartmann](#), [F. Iglesias-Suarez](#), [M. Janssens](#), [E. R. Jones](#), [T. Kölling](#), [M. Lees](#), [S. Lhermitte](#), [R. V. van Nieuwpoort](#), [A.-K. Pahker](#), [O. J. Pellicer-Valero](#), [F. P. Pijpers](#), [A. Siibak](#) ... [F. C. Vossepoel](#) [+ Show authors](#)

[Communications Earth & Environment](#) **5**, Article number: 463 (2024) | [Cite this article](#)

3787 Accesses | **4** Altmetric | [Metrics](#)



Digital twins of the Earth with and for humans

[W. Hazeleger](#) , [J. P. M. Aerts](#), [P. Bauer](#), [M. F. P. Bierkens](#), [G. Camps-Valls](#), [M. M. Dekker](#), [F. J. Doblas-Reyes](#), [V. Eyring](#), [C. Finkenauer](#), [A. Grundner](#), [S. Hachinger](#), [D. M. Hall](#), [T. Hartmann](#), [F. Iglesias-Suarez](#), [M. Janssens](#), [E. R. Jones](#), [T. Kölling](#), [M. Lees](#), [S. Lhermitte](#), [R. V. van Nieuwpoort](#), [A.-K. Pahker](#), [O. J. Pellicer-Valero](#), [F. P. Pijpers](#), [A. Siibak](#), ... [F. C. Vossepoel](#) [+ Show authors](#)

[Communications Earth & Environment](#) **5**, Article number: 463 (2024) | [Cite this article](#)

3787 Accesses | 4 Altmetric | [Metrics](#)

“Incorporating human interactions in digital twins of the Earth represents a transformative frontier, promising unparalleled insights into Earth system dynamics and empower humans for action.”

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



Impact assessment culture in the European Union. Time for something new?

Andrea Saltelli^{a,b,*}, Marta Kuc-Czarnecka^c, Samuele Lo Piano^d, Máté János Lőrincz^d, Magdalena Olczyk^e, Arnald Puy^e, Erik Reinert^{f,g}, Stéfán Thor Smith^d, Jeroen P. van der Sluijs^{b,h}

Nicholas Georgescu-Roegen



Erik S. Reinert



Jerome Ravetz and Silvio Funtowicz