

# Sensitivity auditing

Andrea Saltelli

Facultad de Ciencias Naturales – Universidad  
del Rosario, May 19, 2022

A green-themed poster for a webinar. At the top, it says 'Universidad del Rosario | Facultad de Ciencias Naturales'. The main title is 'WEBINARS' in large yellow letters, followed by 'Sensitivity in sustainability science: a matter of Quality'. It lists two events: 'How not to do a sensitivity analysis' on May 12 (11:00-13:00 Colombia, 18:00-20:00 CET Summer) and 'Sensitivity auditing' on May 19 (7:30 - 9:30 Colombia, 14:30-16:30 CET Summer). A circular photo of Dr. Andrea Saltelli is shown next to the text 'Speaker: Dr. Andrea Saltelli'. Below this, it says 'Centre for the Study of the Sciences and the Humanities, University of Bergen, Norway'. At the bottom right, a yellow box contains the text 'For more details: https://bit.ly/FCN-WEBINARS'. The background features a globe and various scientific icons.

# Where to find this talk: [www.andreasaltelli.eu](http://www.andreasaltelli.eu)

The logo for Andrea Saltelli, featuring the name "Andrea Saltelli" in white text on a teal rectangular background.[HOME](#)[ABOUT ME](#)[PUBLICATIONS](#)[NEWS & VIDEOS](#)[RESOURCES](#)A large background image of a valley with terraced rice fields under a hazy, golden sky. The text "CAETERIS ARE NEVER PARIBUS" is overlaid in white.

CAETERIS ARE  
NEVER PARIBUS

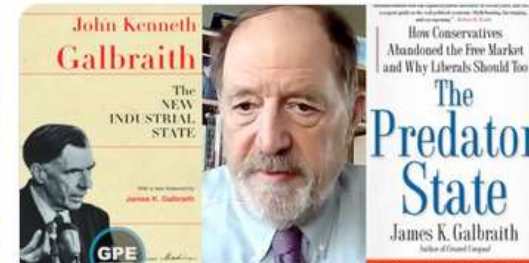
Tweets by [@AndreaSaltelli](#)



**andrea saltelli**  
[@AndreaSaltelli](#)

Worth listening all; pay heed to the bit at 31'.50".  
Why economics needs to pay heed to its  
biophysical bases [@ICTA\\_UAB](#) [@g\\_kallis](#)

Resource Limits to American Capitalism & the  
Predator State Today - % [GPEnewsdocs.com](#)  
% [gpenewsdocs.com/resource-limit...](#)



**Resource Limits to American Capitalis...**

James K. Galbraith discusses the shift of ...  
[gpenewsdocs.com](#)

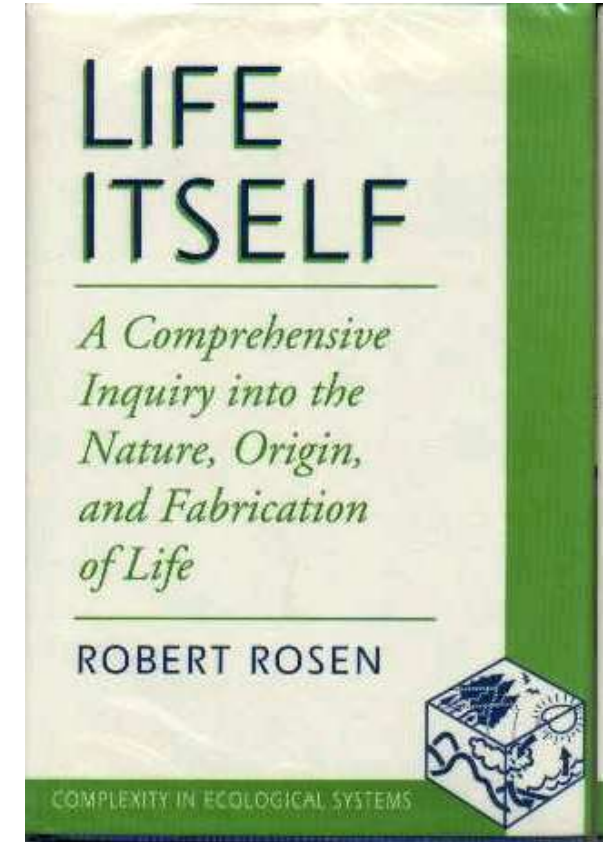
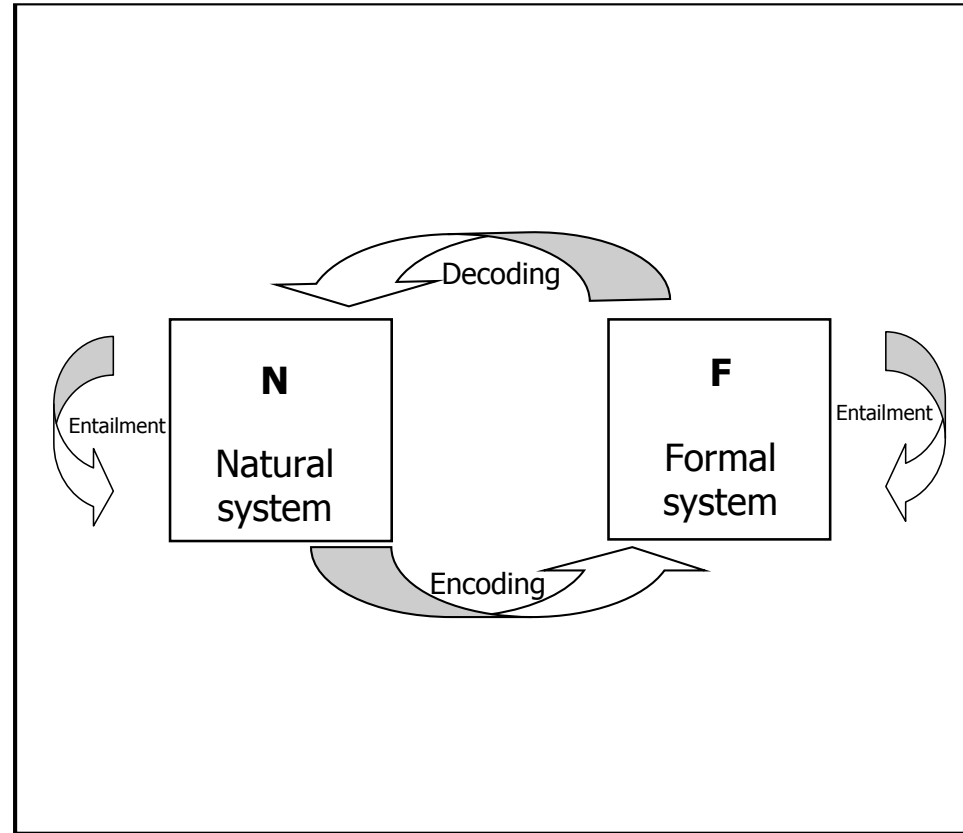
[Embed](#)[View on Twitter](#)

Something general about  
mathematical modelling

Modelling is a  
craft more than  
a science

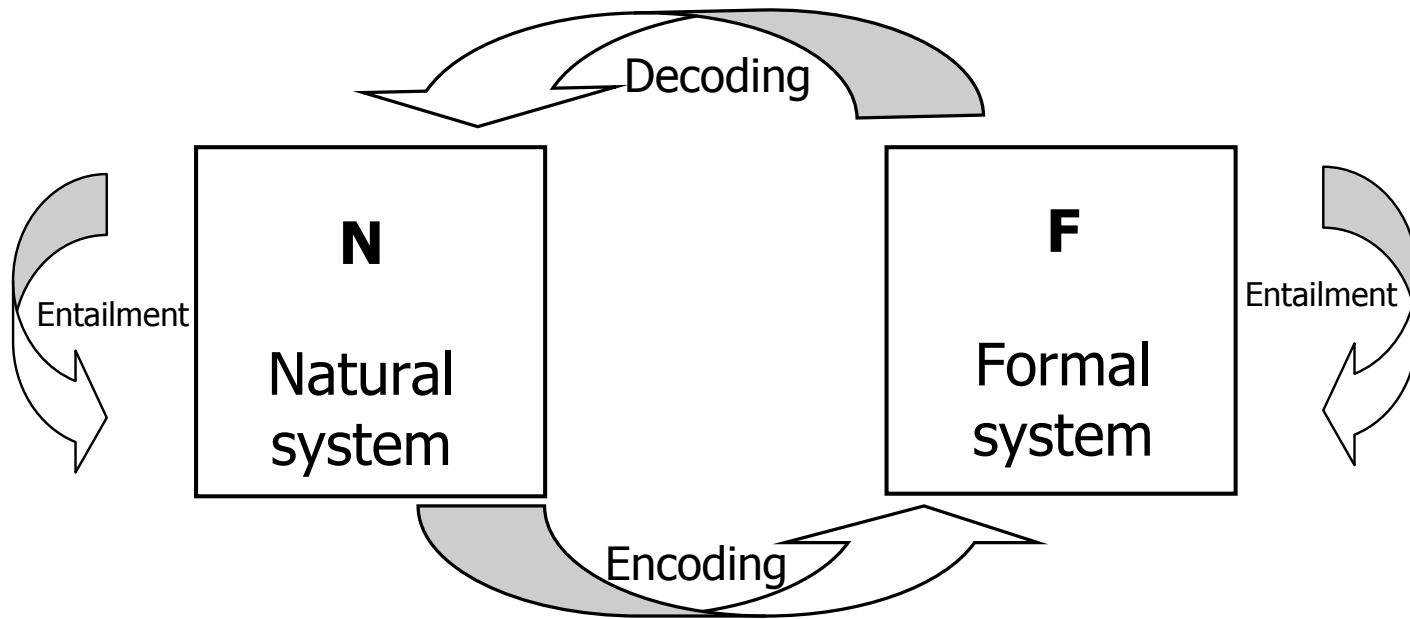


# Modelling as a craft rather than as a science for Robert Rosen



R. Rosen, *Life Itself: A Comprehensive Inquiry Into the Nature, Origin, and Fabrication of Life*. Columbia University Press, 1991.

Louie, A.H. 2010. "Robert Rosen's Anticipatory Systems." Edited by Riel Miller. *Foresight* 12 (3): 18–29. <https://doi.org/10.1108/14636681011049848>.



What is a model ?



Robert Rosen

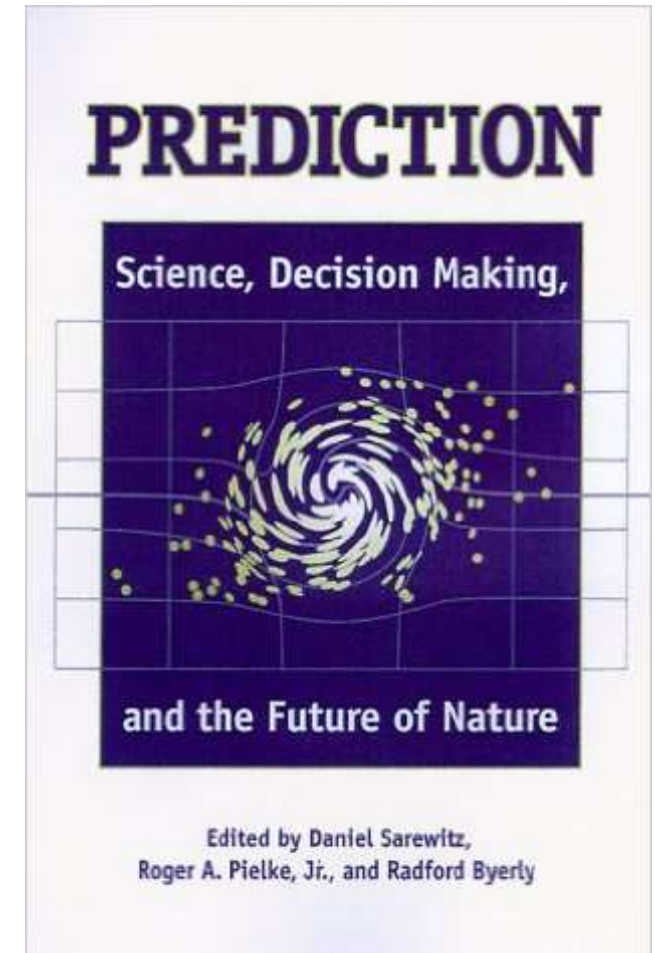
“models are most useful when they are used to challenge existing formulations, rather than to validate or verify them”



Naomi  
Oreskes

N. Oreskes, K. Shrader-Frechette, and K. Belitz, “Verification, Validation, and Confirmation of Numerical Models in the Earth Sciences,” *Science*, 263, no. 5147, 1994.

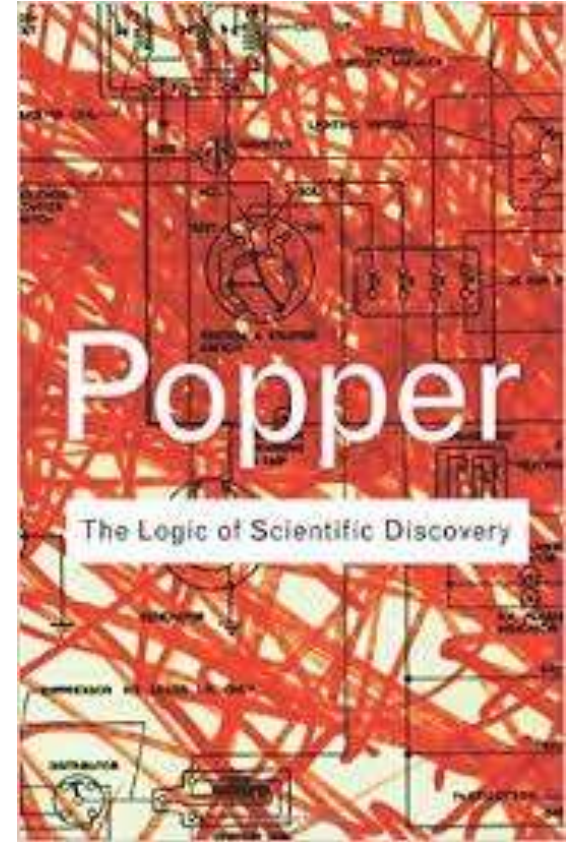
# Models are not physical laws



Oreskes, N., 2000, Why predict? Historical perspectives on prediction in Earth Science, in Prediction, Science, Decision Making and the future of Nature, Sarewitz et al., Eds., Island Press, Washington DC



“[...] to be of value in theory testing, the predictions involved must be capable of refuting the theory that generated them”  
(N. Oreskes)



“When a model generates a prediction, of what precisely is the prediction a test? The laws? The input data? The conceptualization?

Any part (or several parts) of the model might be in error, and there is no simple way to determine which one it is”

Models have  
little memory

“[...] The process of constructing and validating [value-at risk] models is time consuming and detail oriented; normally even the people who produced the model will not remember many of the assumptions incorporated into it, short of redoing their work, which means that the client cannot simply ask then what went into it.”

E. Millgram The Great Endarkenment, p. 29

# Caeteris are never paribus

Ceteris paribus or caeteris paribus is a Latin phrase meaning "all other things being equal" or "other things held constant" or "all else unchanged" (Wikipedia)



# The case of DSGE, dynamic stochastic general equilibrium models

Rational expectations of agents  
Efficient market hypothesis

Philip Mirowski



Philip Mirowski, 2013, Never let a serious crisis go wasted, Verso Books.

The US senate and Queen Elisabeth perplexed...



Philip Mirowski, 2013, Never let a serious crisis go wasted, Verso Books.

Need for better modelling?  
A manifesto



# 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.

>260 references  
SUPPLEMENTARY INFORMATION  
1. Additional information and references



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

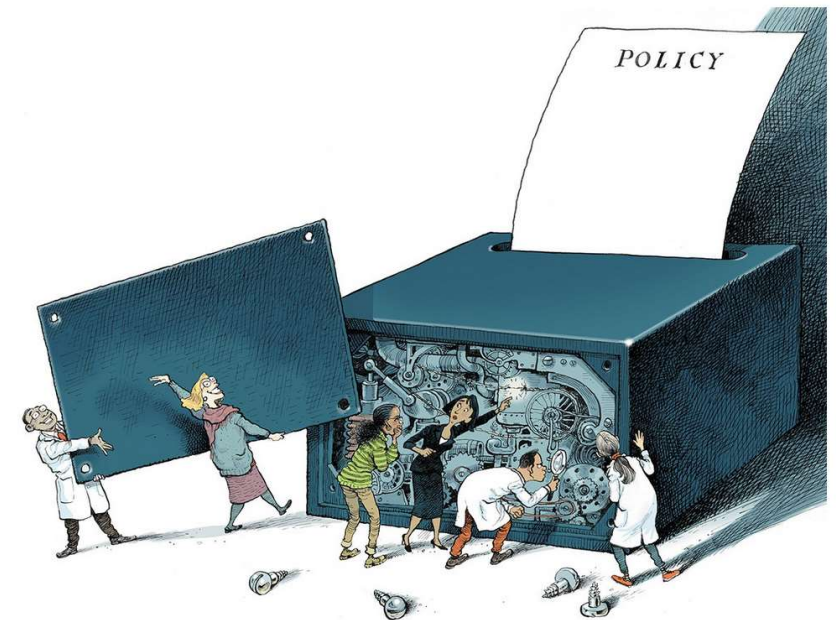
**3 STS scholars** Bammer, Sarewitz, Stirling

**1 philosopher** Ravetz

**1 historian** Charters

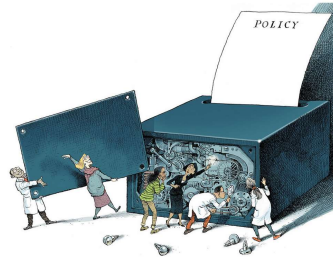
**1 political scientists** Di Fiore

**1 expert RRI - Open Science** Rafols





COVID-19 policies dictated by  
'science' with two digits precision  
in the presence of fundamental  
uncertainties



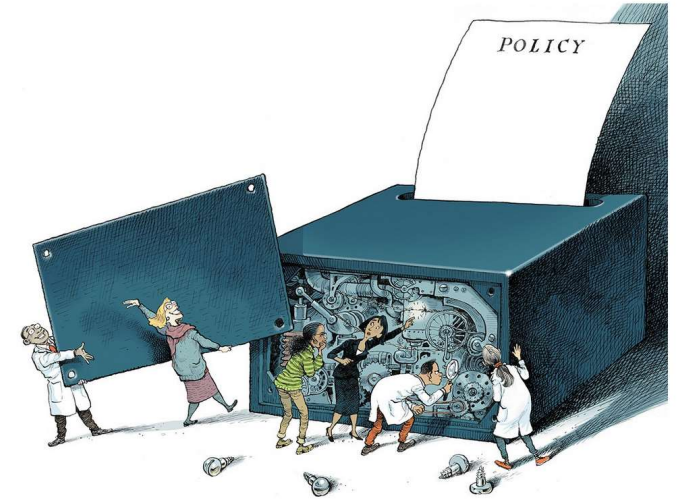
Undocumented research code used  
as a policy tool (chameleon models)



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

COVID has put mathematical models in the limelight

➔ Power & controversy



# Power

The New York Times

## *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.



# Conflicts, when questions of urgency, stakes, values and uncertainty collide

Rush Limbaugh

“Wild-Ass Covid numbers  
... The minute I hear  
anybody start talking about  
models and modeling, I  
blanch”



Rhodes, Tim, and Kari Lancaster. 2020. “Mathematical Models as Public Troubles in COVID-19 Infection Control: Following the Numbers”, *Health Sociology Review* 1–18. doi: 10.1080/14461242.2020.1764376



A 15 m tirade  
against Imperial  
College's model and  
its track record  
from foot and mouse  
disease to COVID-  
19

Bob Seely slams Imperial College and  
modelling

UK, conservative  
MEP.



<https://www.indigoumbrella.co.uk/bob-seely-slams-imperial-college-and-modelling/>



# Mind the assumptions

Assess uncertainty and sensitivity

## Mind the hubris

Complexity can be the enemy of relevance

## Mind the framing

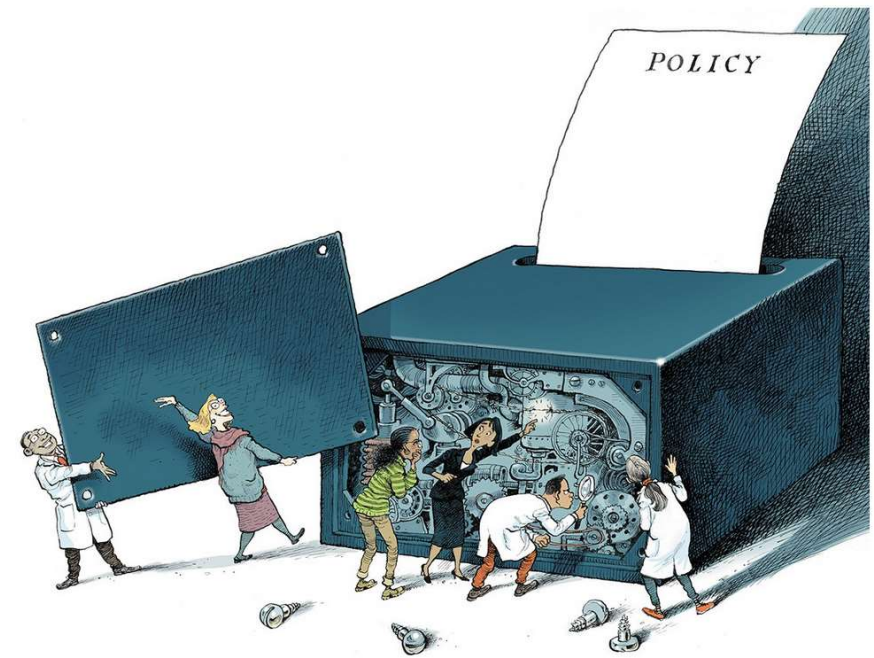
Match purpose and context

## Mind the consequences

Quantification can backfire.

## Mind the unknowns

Acknowledge ignorance

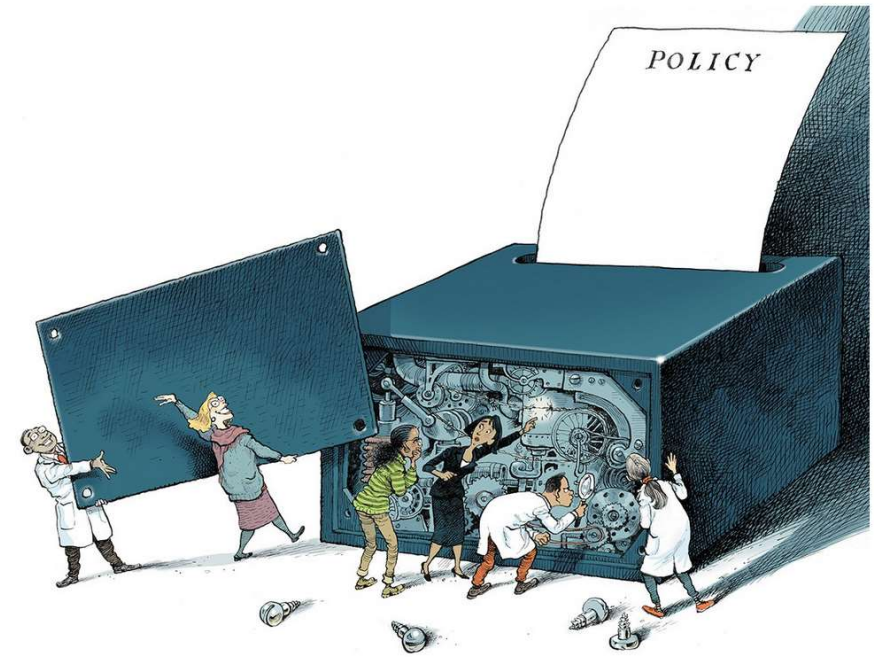


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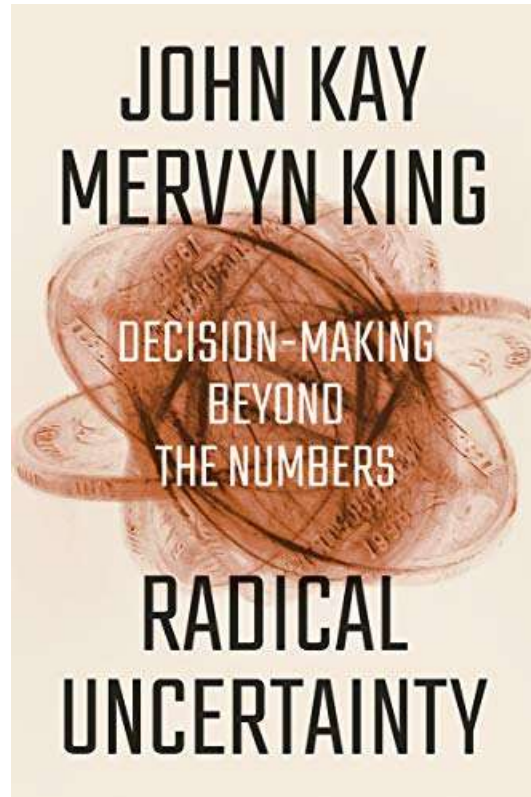
Assess uncertainty and sensitivity



... models require input values for which there is no reliable information...



Models ask as input information which we don't have – The case of WEBTAG



John Kay

## WebTAG: Annual Percentage Change in Car Occupancy (% pa) up to 2036

Journey Purpose	Weekday					Weekend	All Week
	7am-10am	10am-4pm	4pm-7pm	7pm-7am	Weekday Average		
Work	-0.48	-0.4	-0.62	-0.5	-0.44	-0.48	-0.45
Non - Work (commuting and other)	-0.67	-0.65	-0.53	-0.47	-0.59	-0.52	-0.56

Source: J. A. Kay, “Knowing when we don’t know,” 2012,  
[https://www.ifs.org.uk/docs/john\\_kay\\_feb2012.pdf](https://www.ifs.org.uk/docs/john_kay_feb2012.pdf)



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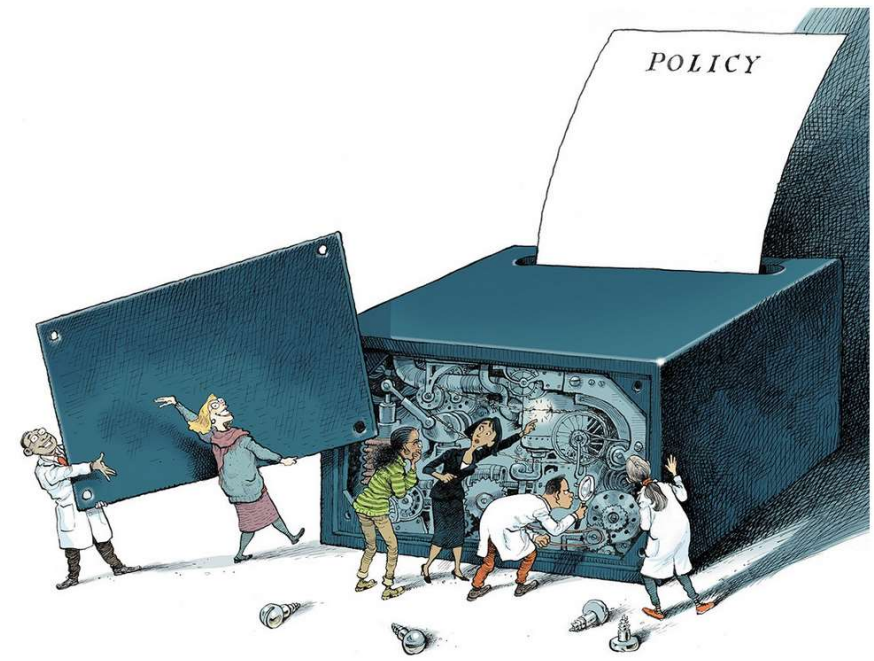
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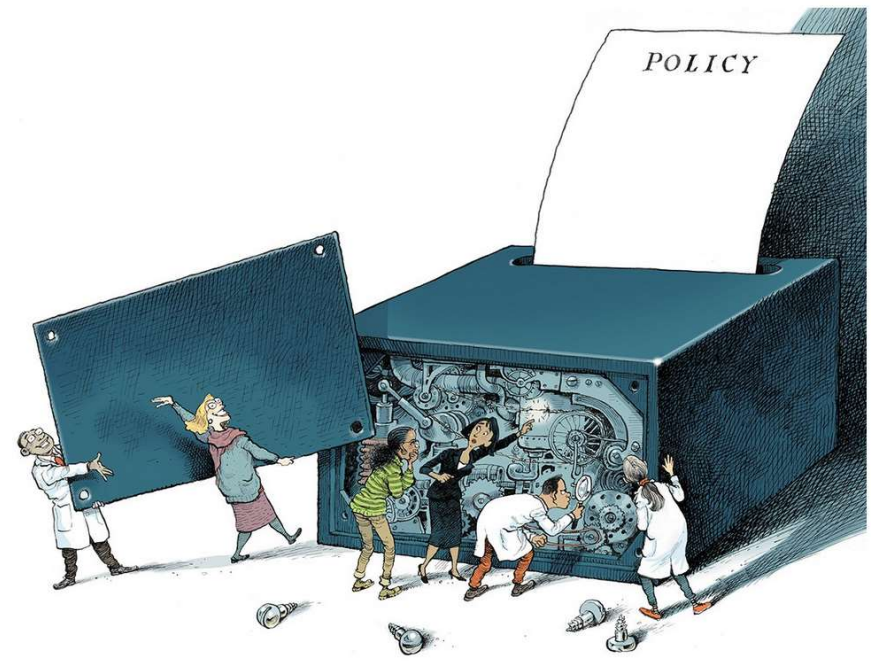
Acknowledge ignorance





# Mind the hubris

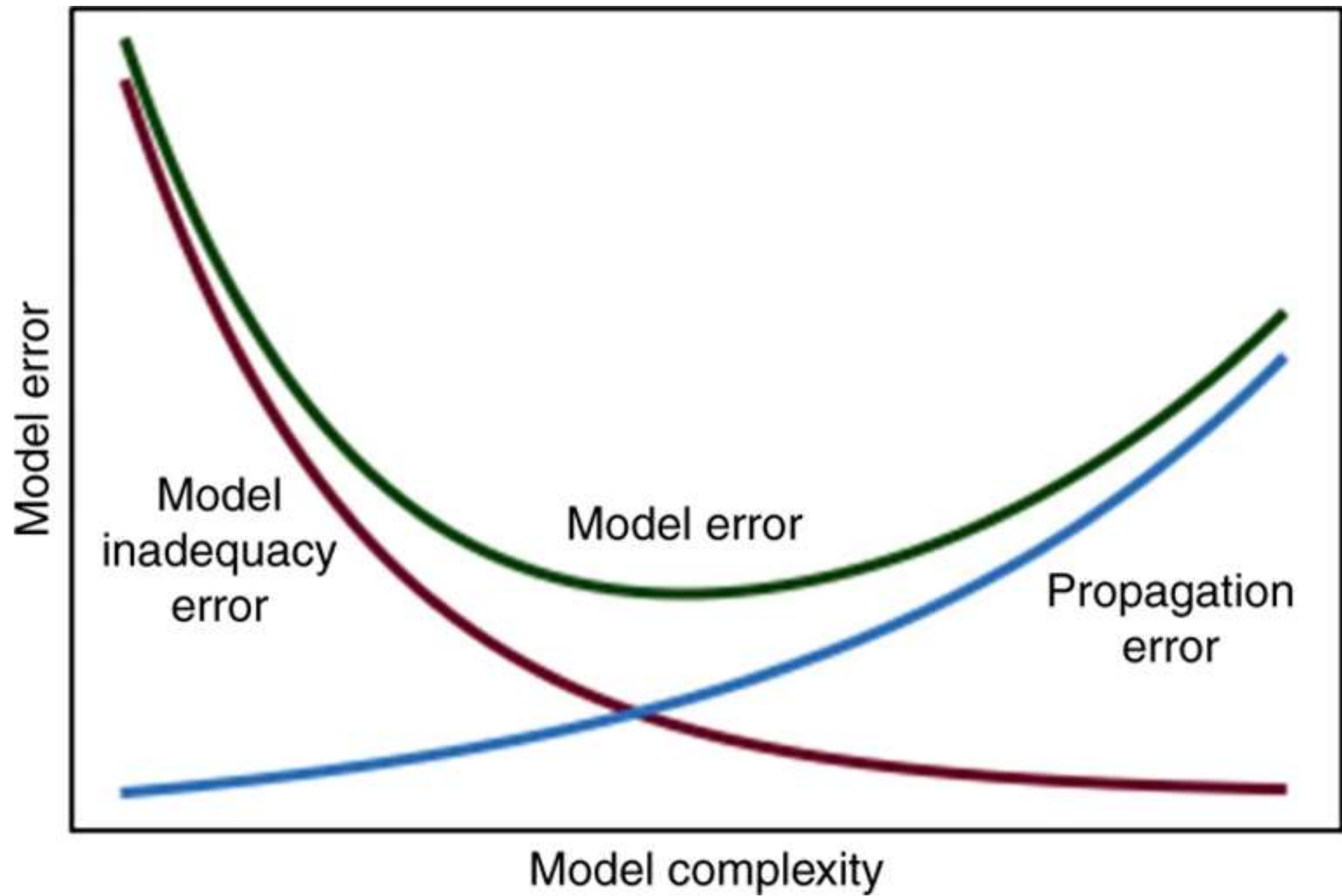
Complexity can be the enemy of relevance



... many are seduced by the idea of adding complexity in an attempt to capture reality more accurately, but...

## SUPPLEMENTARY INFORMATION

1. Additional information and references >260 references



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Complexity can be the enemy of relevance



## Mind the framing

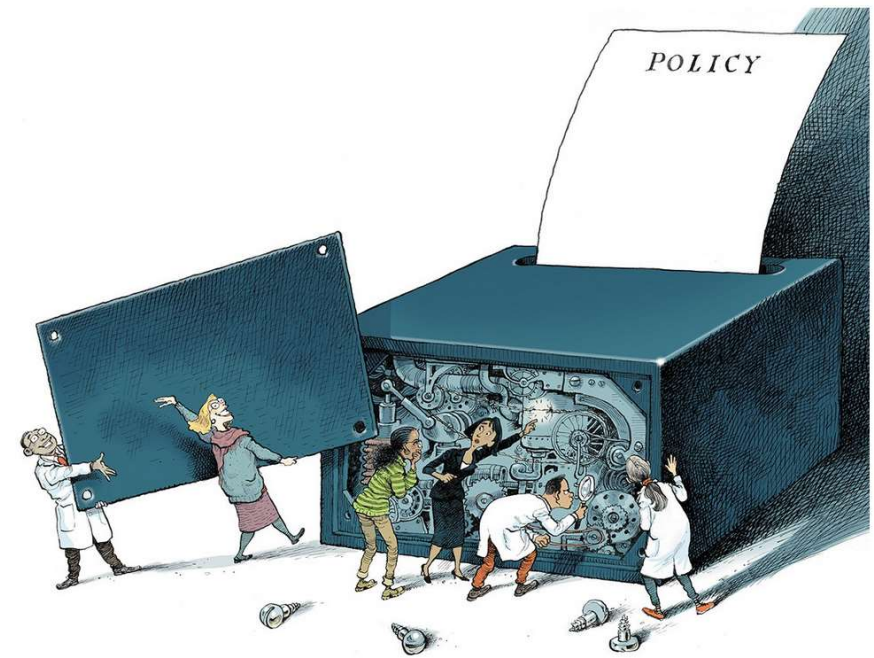
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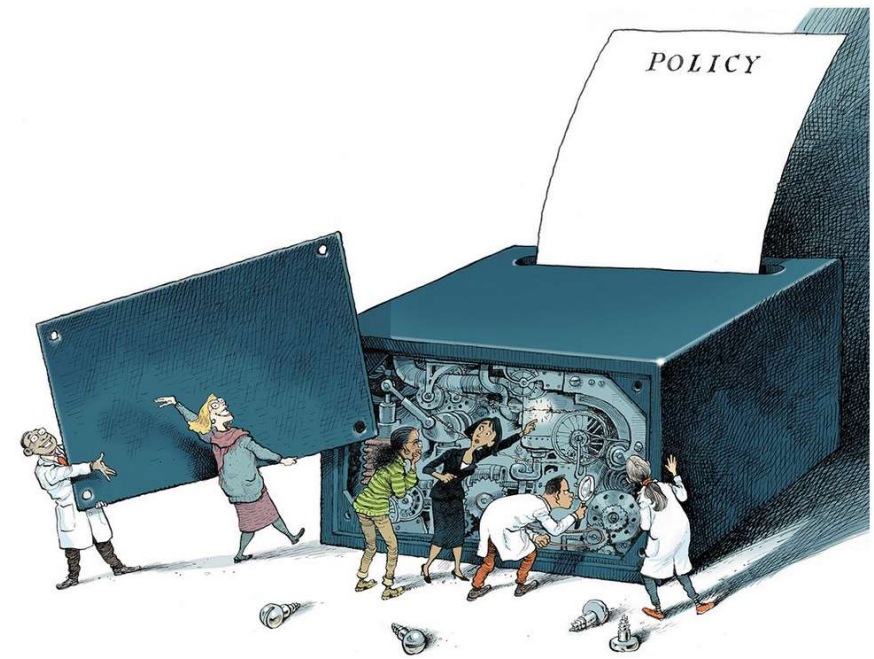
## Mind the unknowns

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# Mind the framing

Match purpose and context



… models will reflect the interests, disciplinary orientations and biases of the developers…

## SUPPLEMENTARY INFORMATION

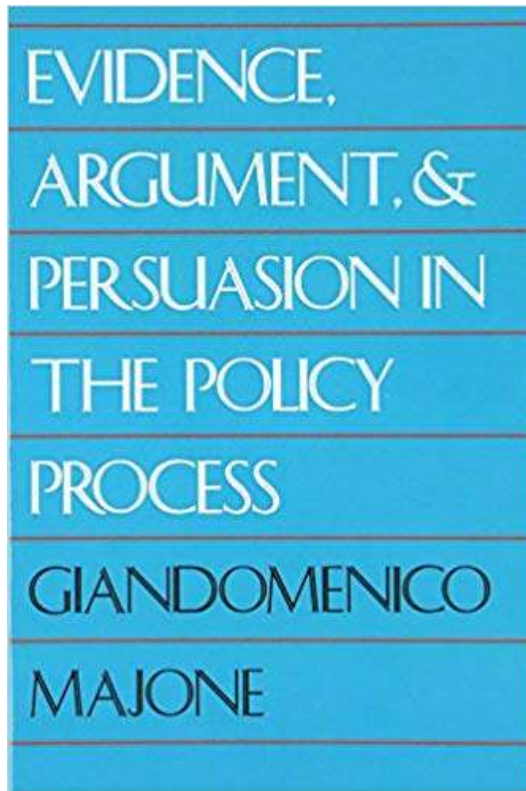
1. Additional information and references >260 references



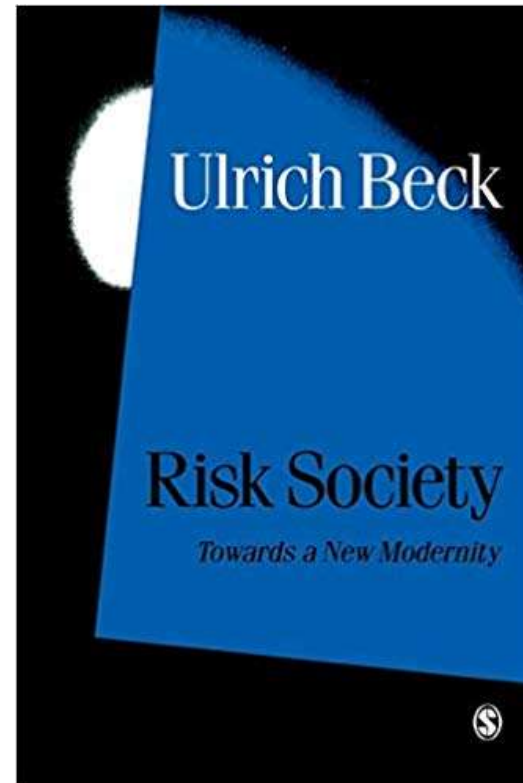
# From Ulrich Beck to Giandomenico Majone: the technique is never neutral



Ulrich Beck  
(1944 –2015)



1989



1992 (1986)



Environmental Science & Policy

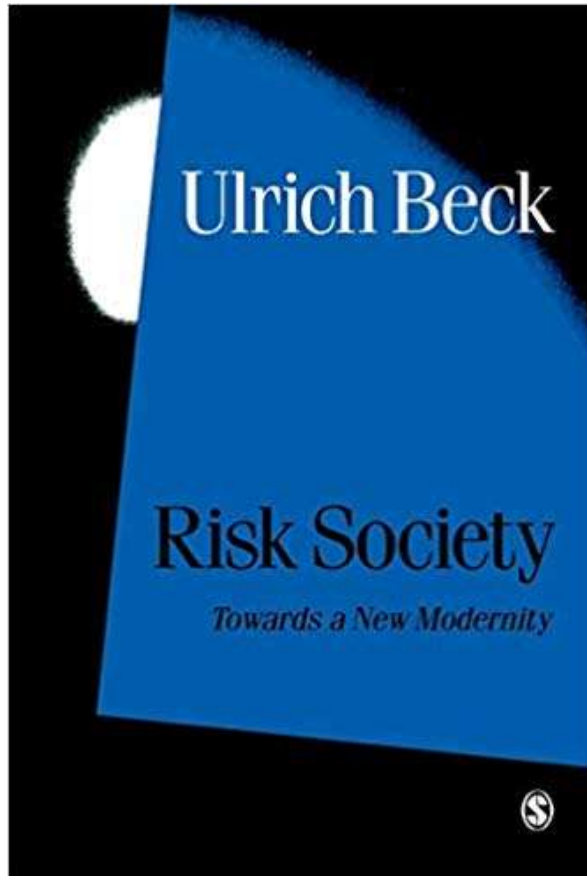
Volume 106, April 2020, Pages 87-98



The technique is never neutral. How  
methodological choices condition the  
generation of narratives for sustainability

Andrea Saltelli <sup>a, b</sup> ✉, Lorenzo Benini <sup>c</sup>, Silvio Funtowicz <sup>a</sup>, Mario Giampietro <sup>d, e</sup>, Matthias Kaiser <sup>a</sup>,  
Erik Reinert <sup>a, f</sup>, Jeroen P. van der Sluijs <sup>a, g, h</sup>

“It is not uncommon for political programs to be decided in advance simply by the choice of what expert representatives are included in the circle of advisers.”



1992 (1986)



Ulrich Beck  
(1944 –2015)



# The technique is never neutral. How methodological choices condition the generation of narratives for sustainability



Environmental Science & Policy  
Volume 106, April 2020, Pages 87–98



Andrea Saltelli <sup>a, b</sup>  , Lorenzo Benini <sup>c</sup>, Silvio Funtowicz <sup>a</sup>, Mario Giampietro <sup>d, e</sup>, Matthias Kaiser <sup>a</sup>, Erik Reinert <sup>a, f</sup>, Jeroen P. van der Sluijs <sup>a, g, h</sup>

Combine more lenses, including Post-normal science (PNS), Bioeconomics, and Non-Ricardian economics

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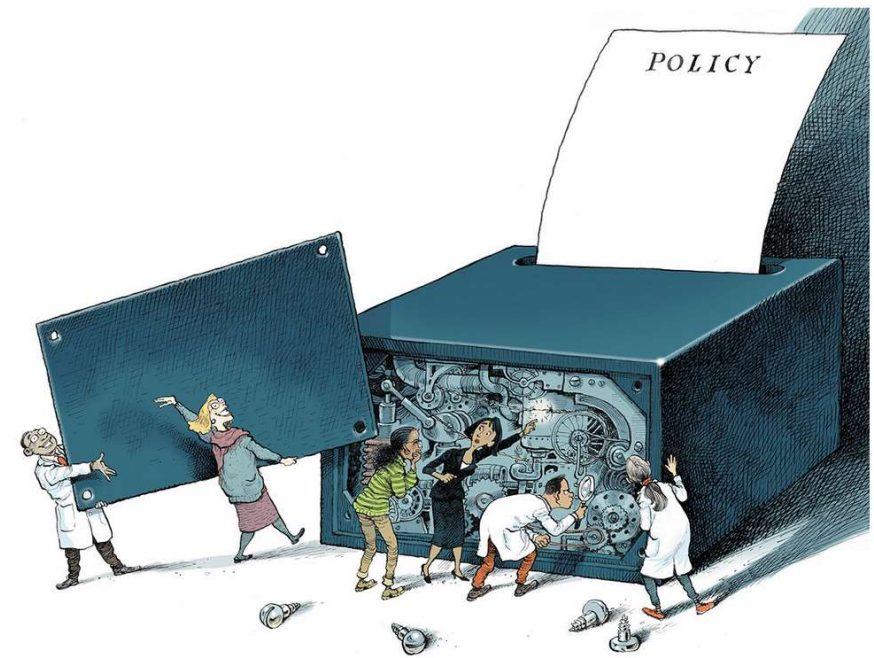


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Quantification can backfire.

## Mind the unknowns

Acknowledge ignorance



# Mind the consequences

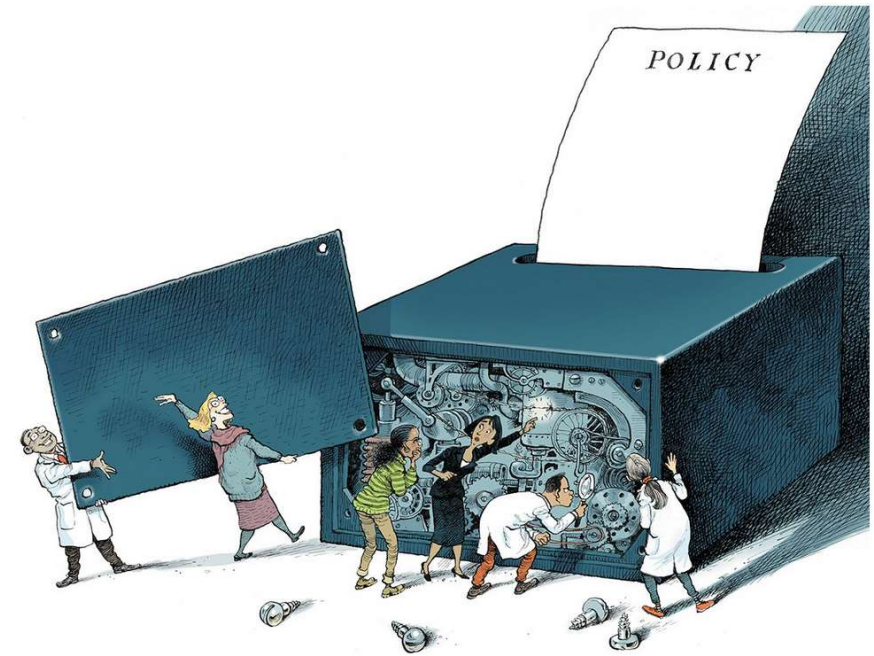
## Quantification can backfire.

[« Back to Article](#)

WIRED MAGAZINE: 17.03

### Recipe for Disaster: The Formula That Killed Wall Street

By Felix Salmon 02.23.09



$$\Pr[T_A < 1, T_B < 1] = \Phi_2(\Phi^{-1}(F_A(1)), \Phi^{-1}(F_B(1)), \gamma)$$

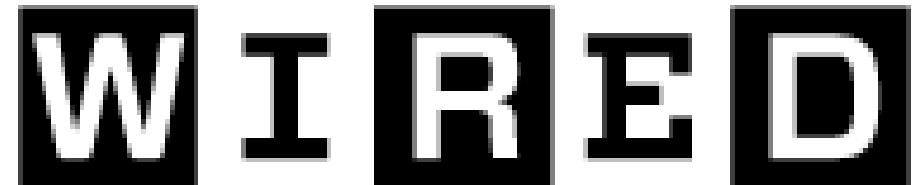
Here's what killed your 401(k) *David X. Li's Gaussian copula function as first published in 2000. Investors exploited it as a quick—and fatally flawed—way to assess risk. A shorter version appears on this month's cover of Wired.*

Here is what killed your 401(k)...

Li's Gaussian copula function ...

**Nassim Nicholas Taleb**, hedge fund manager and author of *The Black Swan*, is particularly harsh when it comes to the copula. "People got very excited about the Gaussian copula because of its mathematical elegance, but the thing never worked," he says. "Co-association between securities is not measurable using correlation," because past history can never prepare you for that one day when everything goes south. "Anything that relies on correlation is charlatanism."

Felix Salmon, Wired, February 2009



Source: <https://www.wired.com/2009/02/wp-quant/>



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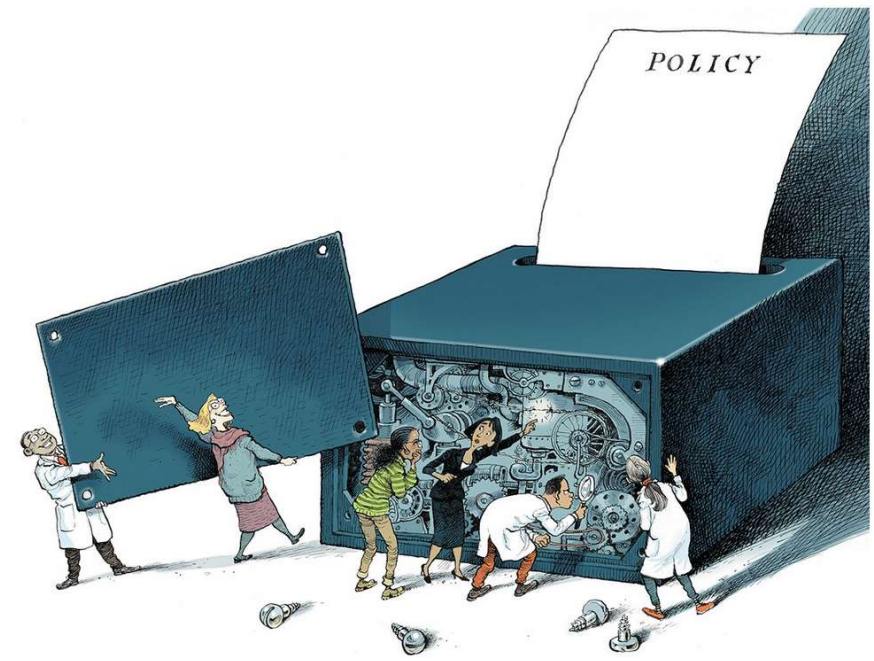
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## Mind the unknowns

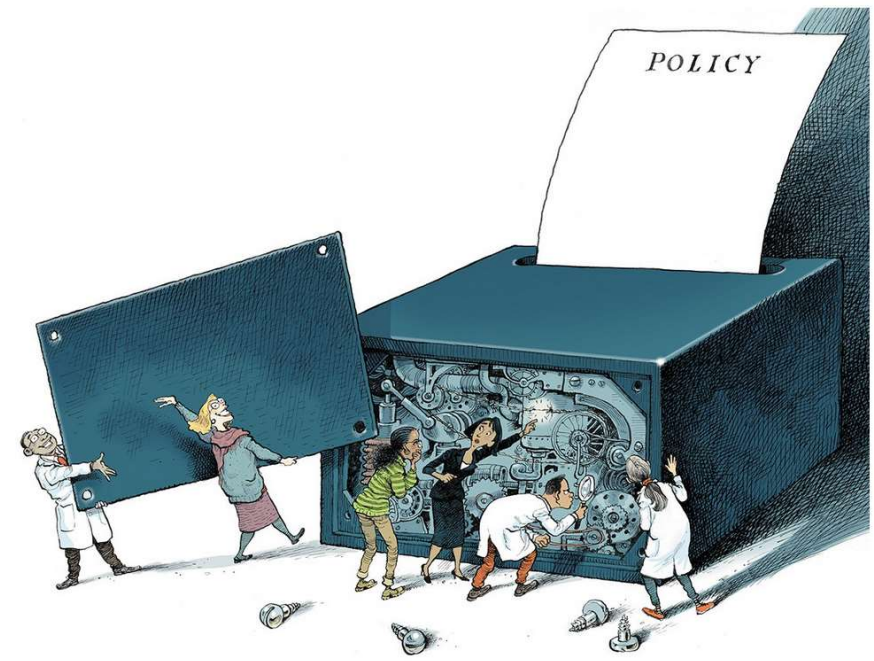
Acknowledge ignorance





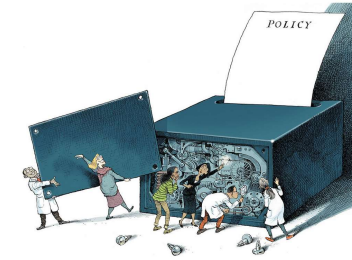
# Mind the unknowns

## Acknowledge ignorance



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

“There is no number-answer to your question”



Anthony Fauci

March 12, 2020, Anthony Fauci before the House Oversight and Reform Committee  
[https://archive.org/details/CSPAN\\_20200314\\_141500\\_Dr.\\_Redfield\\_Dr.\\_Fauci\\_\\_Others\\_Testify\\_on\\_Coronavirus\\_Response\\_Part\\_1](https://archive.org/details/CSPAN_20200314_141500_Dr._Redfield_Dr._Fauci__Others_Testify_on_Coronavirus_Response_Part_1)

Reproducibility

is a necessary  
condition for

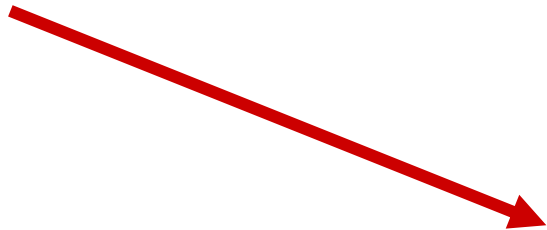
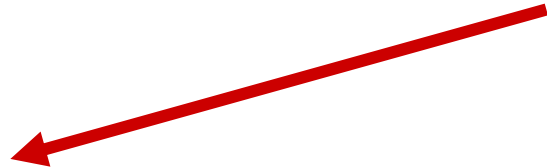
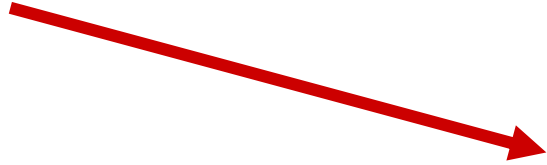
Transparency

is a necessary  
condition for

Legitimacy

is a necessary  
condition for

Epistemic authority



Sensitivity auditing

# EC impact assessment guidelines: sensitivity analysis & auditing



*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](https://ec.europa.eu/info/law/law-making-process/planning-and-proposing-law/better-regulation-why-and-how/better-regulation-guidelines-and-toolbox_en)



# Sensitivity auditing in the EC Guidelines (p. 563)

“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.”



*Better Regulation*  
**TOOLBOX**

November 2021

## Sensitivity auditing in the EC Guidelines (p. 563)

“In general, sensitivity auditing stresses the idea of clearly communicating the extent to which particular models can be used to support policy decisions and their results can be trusted, taking into account as much as possible all forms of potential uncertainty, ...”



*Better Regulation*  
**TOOLBOX**

November 2021

# Sensitivity auditing in the EC Guidelines (p. 563)

“... and to anticipate criticism by third parties. In particular, one should avoid giving the impression of false confidence by ‘quantification at all costs’.”



*Better Regulation*  
**TOOLBOX**

November 2021

# Sensitivity auditing in the EC Guidelines (p. 563)

“In some cases there is simply not enough data, or the process is too complex, to give a meaningful quantitative prediction.”



*Better Regulation*  
**TOOLBOX**

November 2021

# Sensitivity Auditing



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

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Saltelli, A., Guimarães Pereira, Â.,  
Van der Sluijs, J.P. and Funtowicz, S.



Ângela Guimarães Pereira

# The rules of sensitivity auditing

1. Check against rhetorical use of mathematical modelling;
2. Adopt an “assumption hunting” attitude; focus on unearthing possibly implicit assumptions;
3. Check if uncertainty been instrumentally inflated or deflated.

4. Find sensitive assumptions before these find you; do your SA before publishing;
5. Aim for transparency; Show all the data;
6. Do the right sums, not just the sums right;
7. Perform a proper global sensitivity analysis.

# The End

@andreasaltelli

