



Sensitivity Analysis

Andrea Saltelli

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MNF990 / Theory of Science and Ethics, Bergen,
September 2020



Where to find this talk: www.andreasaltelli.eu

Andrea
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CAETERIS ARE
NEVER PARIBUS

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#statistiques #probabilités #modélisation
#prédiction Isabelle Bruno du #CERAPS
@univ_lille @CNRS_HdF @ScPoLille nous parle
des dérives de la #quantophrénie dans un article à
lire sur le media @FR_Conversation
https://twitter.com/FR_Conversation/status/1302651033164881920

♡ ↗

Sep 7, 2020

andrea saltelli
@AndreaSaltelli

Pour mes amis francophones. Honoured to be co-
author of a statactivist like Isabelle Bruno du
#CERAPS @univ_lille @CNRS_HdF @ScPoLille
@OpenEvidence @UOCNews
Statistiques et modèles mathématiques : doit-on

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Why something technical in
this course





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 ^{a, b}  , Lorenzo Benini ^c, Silvio Funtowicz ^a, Mario Giampietro ^{d, e}, Matthias Kaiser ^a, Erik Reinert ^{a, f}, Jeroen P. van der Sluijs ^{a, g, h}

Something general about
mathematical modelling

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.

An ethical problem in
the use of models in
economics?

Paul Romer's Mathiness = use of mathematics to veil normative stances

Erik Reinert: scholastic tendencies in the mathematization of economics

P. M. Romer, "Mathiness in the Theory of Economic Growth," *Am. Econ. Rev.*, vol. 105, no. 5, pp. 89–93, May 2015.

E. S. Reinert, "Full circle: economics from scholasticism through innovation and back into mathematical scholasticism," *J. Econ. Stud.*, vol. 27, no. 4/5, pp. 364–376, Aug. 2000.

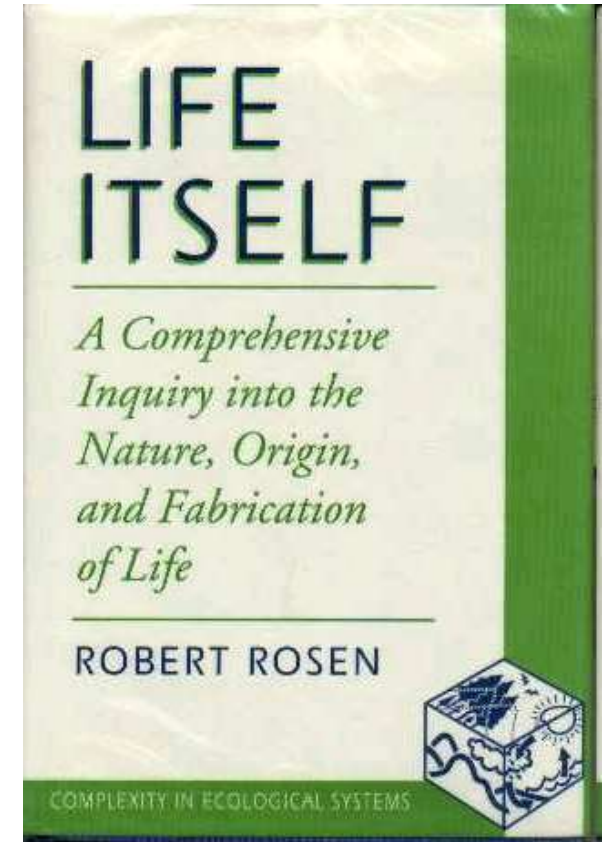
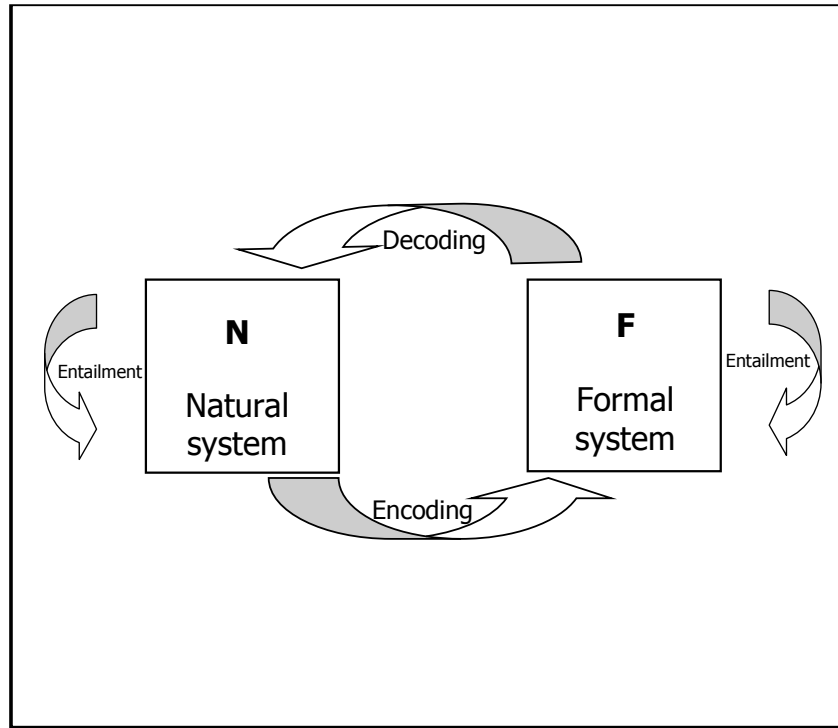
Models have
little memory

“[...] 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.”

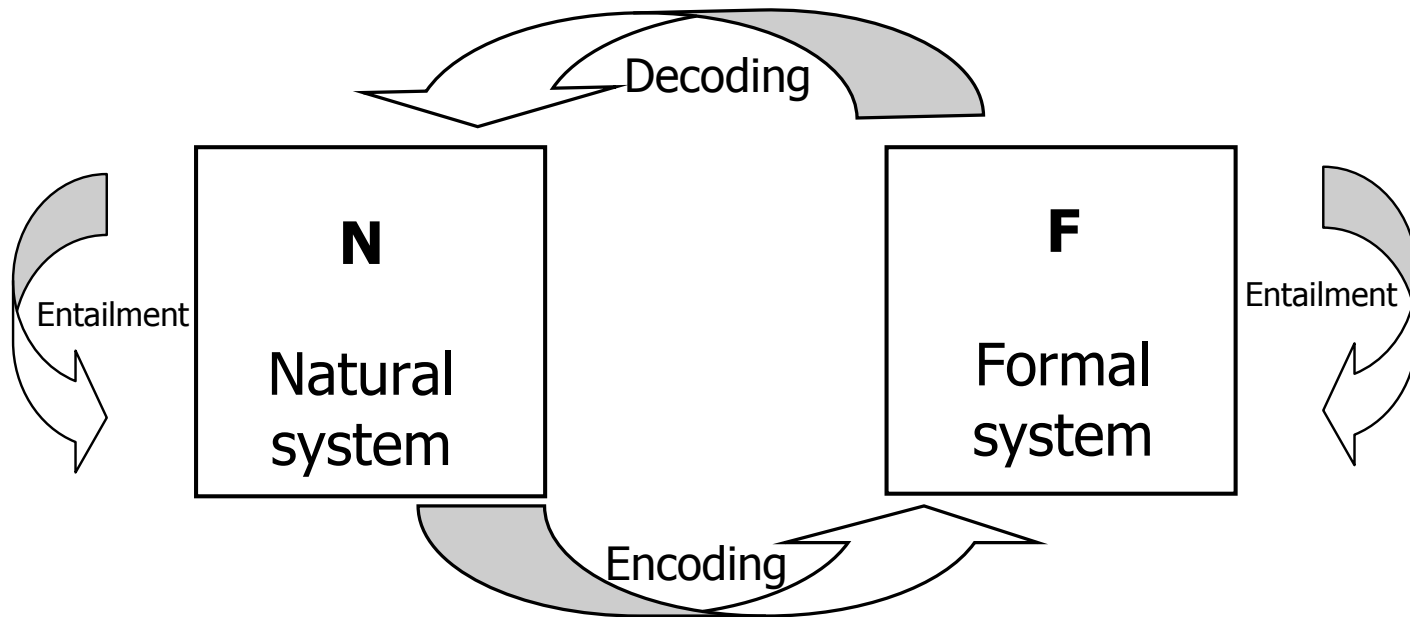
E. Millgram The Great Endarkenment, p. 29

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.



What is a model ?



Robert Rosen

Can models be
falsified?

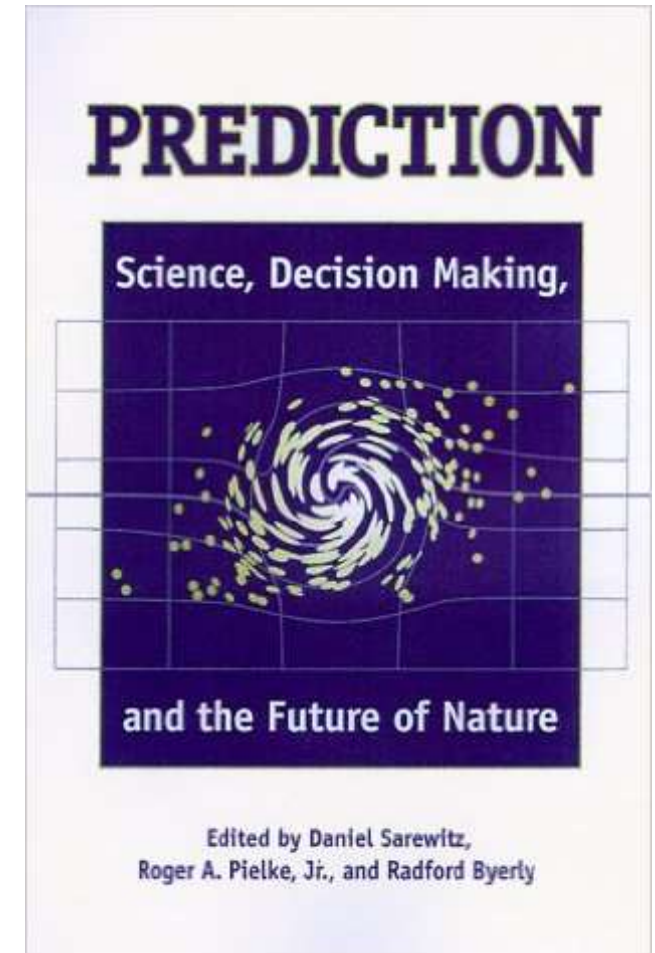
“models are most useful when they are used to challenge existing formulations, rather than to validate or verify them”



Naomi
Oreskes

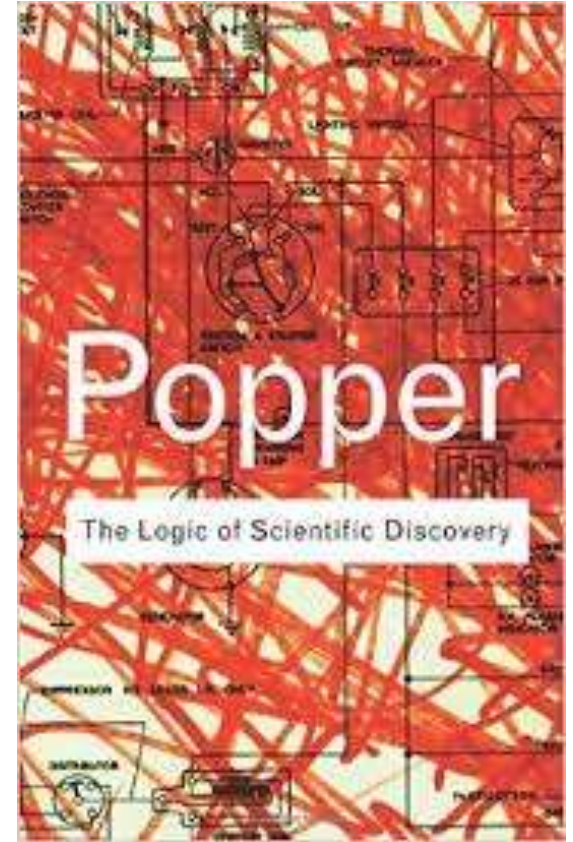
N. Oreskes, K. Shrader-Frechette, and K. Belitz, “Verification, Validation, and Confirmation of Numerical Models in the Earth Sciences,” *Science*, 263, no. 5147, 1994.

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)



“In many cases, these temporal predictions **are treated with the same respect** that the hypothetic–deductive model of science accords to logical predictions. But this respect is largely misplaced”

“[...] models are complex amalgam of theoretical and phenomenological laws (and the governing equations and algorithms that represent them), empirical input parameters, and a model conceptualization [...] 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”

Model-based knowing
is conditional

When models need as input information
which we don't have

John Kay

J. A. Kay, “Knowing when we don't know,” 2012,
https://www.ifs.org.uk/docs/john_kay_feb2012.pdf



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

Models and their data

“[in climate modelling] it looks very little like our idealized image of science, in which pure theory is tested with pure data. [impossible to] eliminate the model-dependency of data or the data-ladenness of models”

Paul N. Edwards, 1999, Global climate science, uncertainty and politics: Data-laden models, model-filtered data.

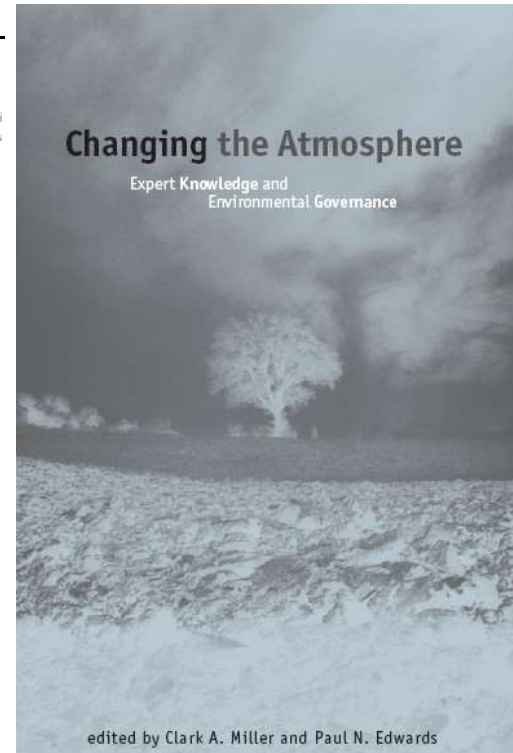
For philosophers Frederick Suppe and Stephen Norton the blurry model/data relationship pervades all science

3

Why Atmospheric Modeling Is Good Science

Stephen D. Norton and Frederick Suppe

Changing the Atmosphere: Expert Knowledge and Environmental Governance, edited by Clark A. Miller, Paul N. Edwards,

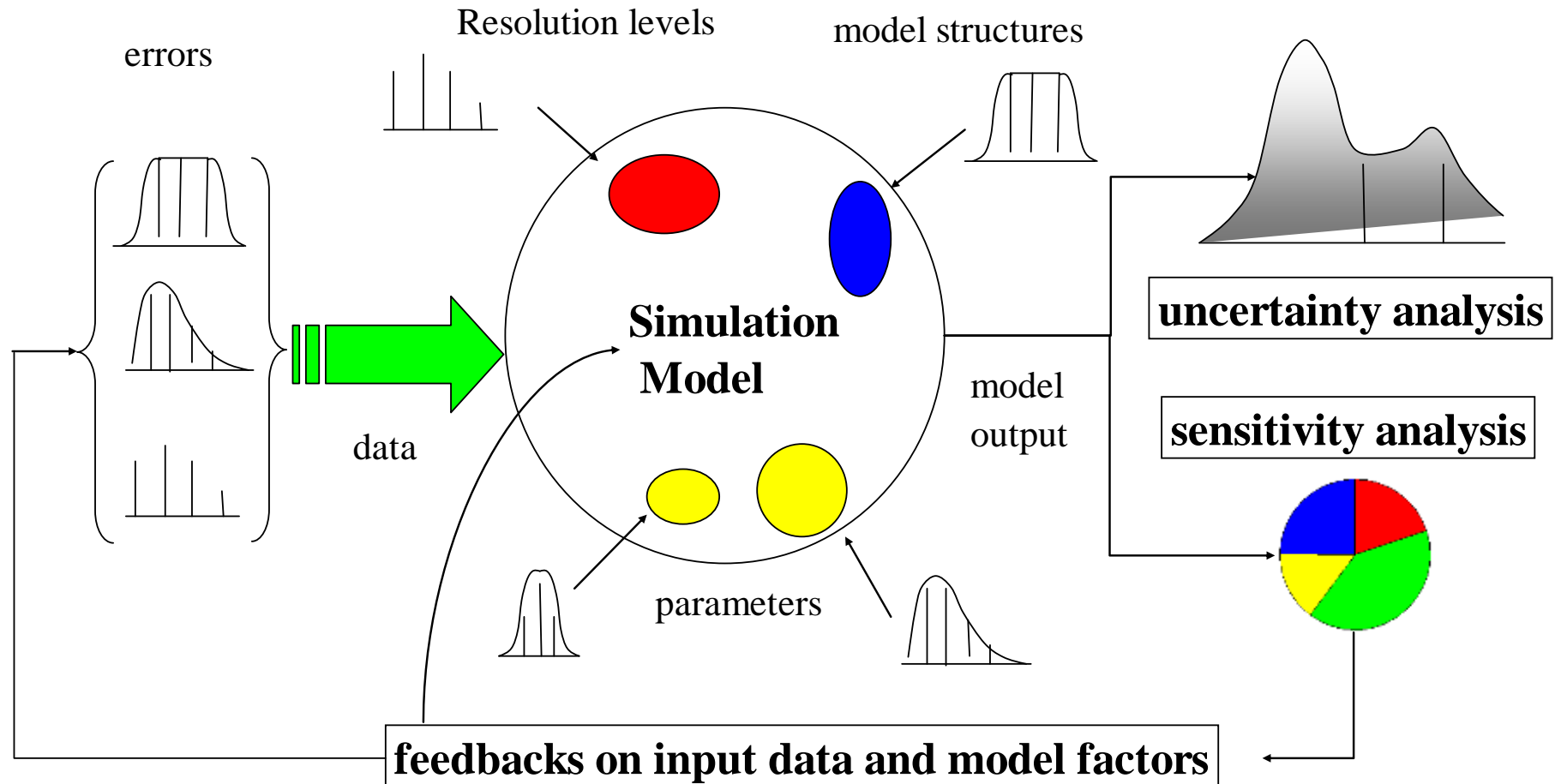


Definitions

Uncertainty analysis: Focuses on just quantifying the uncertainty in model output

Sensitivity analysis: The study of the relative importance of different input factors on the model output

An engineer's vision of UA, SA

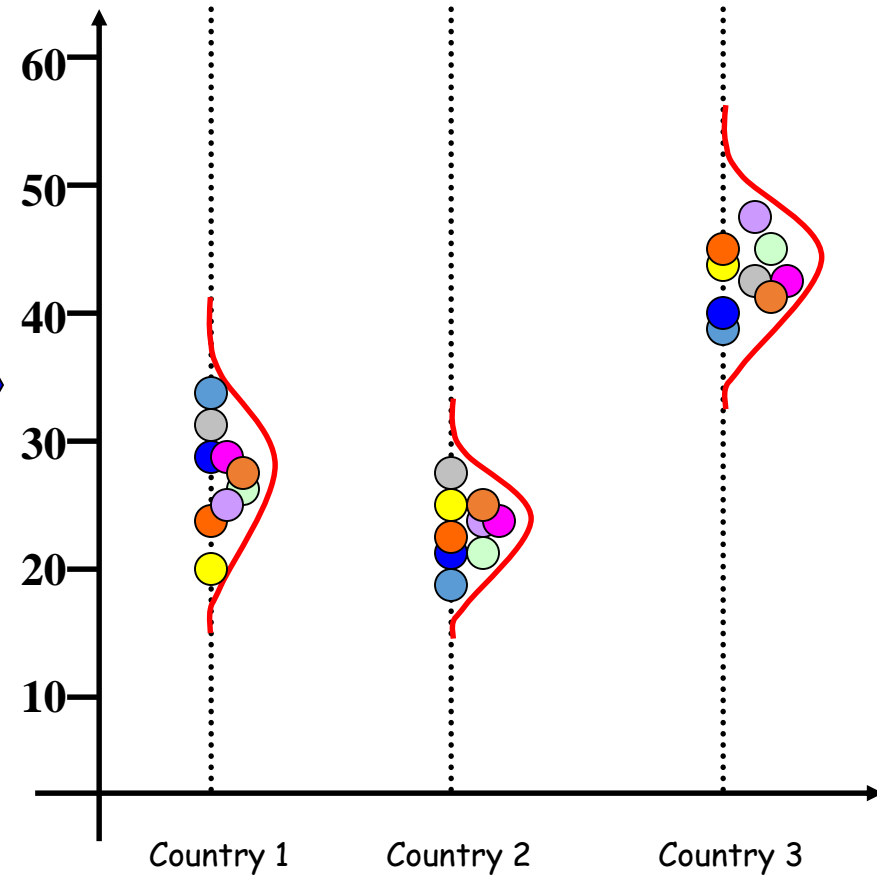
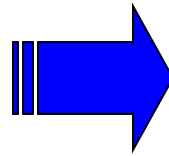
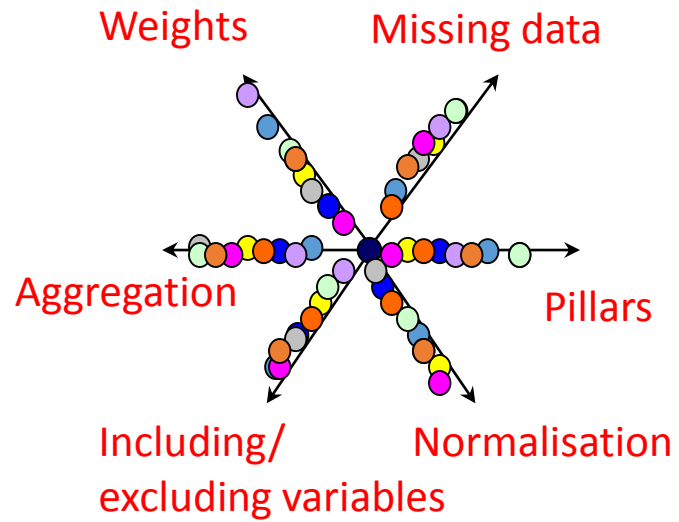


One can sample more than just factors:

- modelling assumptions,
- alternative data sets,
- resolution levels,
- scenarios ...

Assumption	Alternatives
Number of indicators	<ul style="list-style-type: none">▪ all six indicators included or one-at-time excluded (6 options)
Weighting method	<ul style="list-style-type: none">▪ original set of weights,▪ factor analysis,▪ equal weighting,▪ data envelopment analysis
Aggregation rule	<ul style="list-style-type: none">▪ additive,▪ multiplicative,▪ Borda multi-criterion

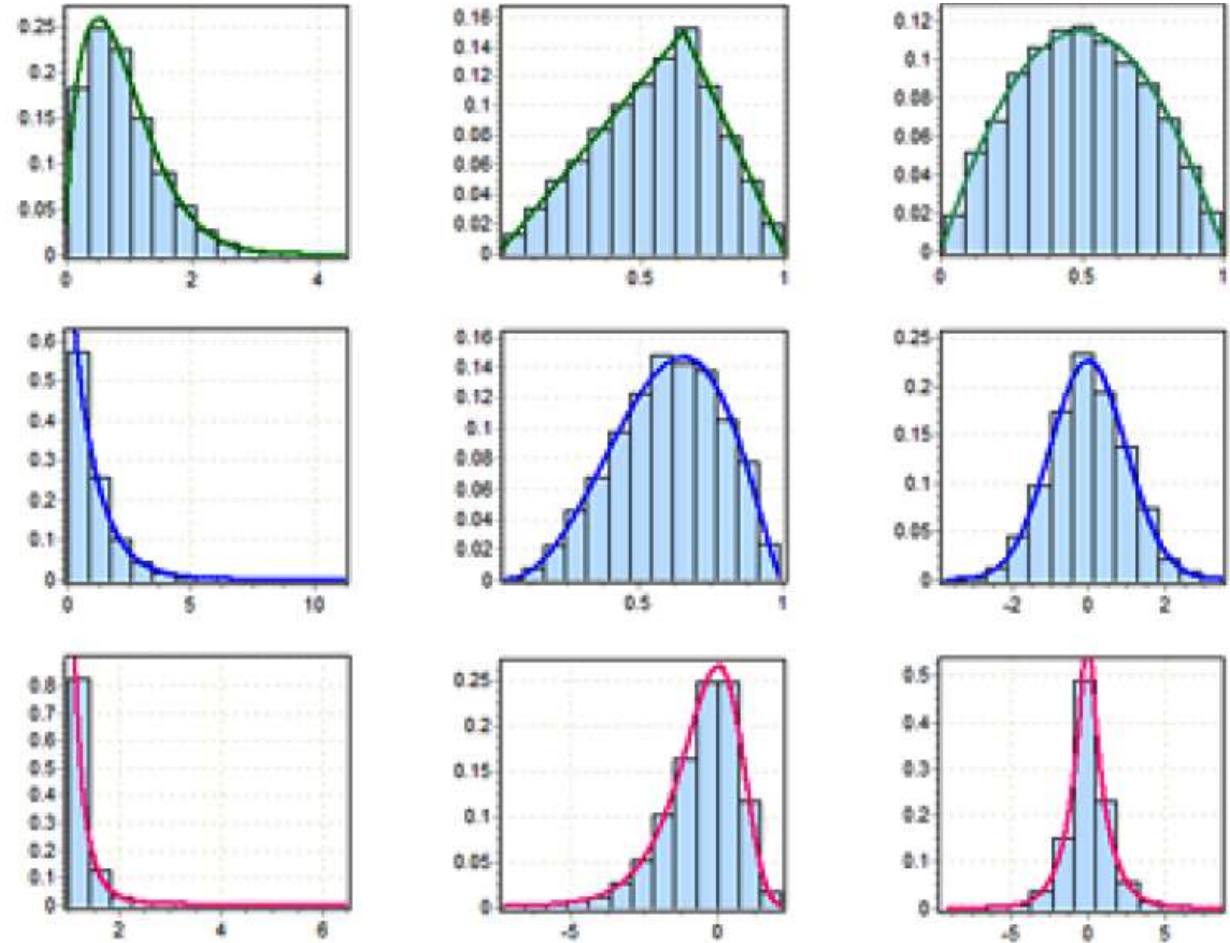
Space of alternatives



x_{11}	x_{12}	...	x_{1k}
x_{21}	x_{22}	...	x_{2k}
...
x_{N1}	x_{N2}	...	x_{Nk}

Each column is a sample from the distribution of a factor

Each row is a sample trial to generate a value of y



Examples of distributions of input factors

Why Sensitivity analysis?

It is in the guidelines!

European Commission, 2015

Office for the Management and Budget, 2006


Environmental Protection Agency, 2009

EPA, 2009, March. Guidance on the Development, Evaluation, and Application of Environmental Models. Technical Report EPA/100/K-09/003. Office of the Science Advisor, Council for Regulatory Environmental Modeling, <http://nepis.epa.gov/Exe/ZyPDF.cgi?Dockkey=P1003E4R.PDF>, Last accessed December 2015.

EUROPEAN COMMISSION, Better regulation toolbox, appendix to the Better Regulation Guidelines, Strasbourg, 19.5.2015, SWD(2015) 111 final, COM(2015) 215 final, http://ec.europa.eu/smart-regulation/guidelines/docs/swd_br_guidelines_en.pdf.

OMB, Proposed risk assessment bulletin, Technical report, The Office of Management and Budget's – Office of Information and Regulatory Affairs (OIRA), January 2006, https://www.whitehouse.gov/sites/default/files/omb/assets/omb/inforeg/proposed_risk_assessment_bulletin_010906.pdf, pp. 16–17, accessed December 2015.

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Better Regulation

European Commission > Better Regulation > Guidelines

Home

REFIT

Stakeholder consultations

Roadmaps / Inception Impact Assessments

Impact Assessment

Evaluation

Regulatory Scrutiny Board

Guidelines

■ Better Regulation Guidelines

■ Better Regulation "Toolbox"

Key documents

Better Regulation Guidelines

These guidelines explain what Better Regulation is and how it should be applied in the day to day practices when preparing new initiatives and proposals or managing existing policies and legislation.

They cover the whole policy cycle, from policy preparation and adoption to implementation and application, to evaluation and revision of EU law. For each of these phases there are a number of Better Regulation principles, objectives, tools and procedures to make sure that the EU has the best regulation possible. These relate to planning, impact assessment, stakeholder consultation, implementation and evaluation.

The [Better Regulation Guidelines](#) are structured into chapters which cover each of the instruments of the law-making process. The corresponding [toolbox](#) gives more detailed and technical information.

Better Regulation Guidelines are based on the outcomes of public consultation exercises carried out in 2013 and 2014.

- [Public consultation on the revision of the Commission's Impact Assessment Guidelines](#)
- [Stakeholder Consultation Guidelines](#)
- [Consultation on the draft Commission Evaluation Policy Guidelines](#)

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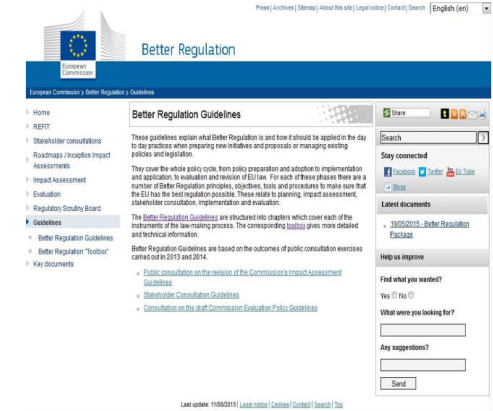
Source: IA Toolbox, p. 391

4. SENSITIVITY AND UNCERTAINTY ANALYSES

Page 391

Six steps for a global SA:

1. Select one output of interest;
2. Participatory step: discuss which input may matter;
3. Participatory step (extended peer review): define distributions;
4. Sample from the distributions;
5. Run (=evaluate) the model for the sampled values;
6. Obtain in this way bot the uncertainty of the prediction and the relative importance of variables.



Is something wrong with this statement (p. 384 of EC guidelines)

The influence of the key variables
should be investigated by a sensitivity analysis.



The screenshot shows the 'Better Regulation' section of the European Commission's website. The header includes the European Commission logo and the text 'Better Regulation'. Below the header, there is a navigation menu with links to Home, REFIT, Stakeholder consultations, Roadmaps / Inception Impact Assessments, Impact Assessment, Evaluation, Regulatory Scrutiny Board, Guidelines (highlighted), Better Regulation Guidelines, Better Regulation 'Toolbox', and Key documents. The main content area is titled 'Better Regulation Guidelines' and contains a search bar, social media links (Facebook, Twitter, YouTube, LinkedIn), and a list of latest documents, including '19/05/2015 - Better Regulation Package'. There is also a 'Help us improve' section with a feedback form.

Why Sensitivity analysis?

It can answer interesting
questions

EVIDENCE,
ARGUMENT, &
PERSUASION IN
THE POLICY
PROCESS

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?"

Why sensitivity analysis?

It can detect garbage in garbage out
(GIGO)

Funtowicz & Ravetz's GIGO (Garbage In, Garbage Out) Science “where uncertainties in inputs must be suppressed least outputs become indeterminate”



Leamer's “Conclusions are judged to be sturdy only if the neighborhood of assumptions is wide enough to be credible and the corresponding interval of inferences is narrow enough to be useful”

S. Funtowicz and J. R. Ravetz, *Uncertainty and Quality in Science for Policy*. Dordrecht: Kluwer, 1990; E. E. Leamer, “Sensitivity Analyses Would Help,” *Am. Econ. Rev.*, vol. 75, no. 3, pp. 308–313, 1985.

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

The case of Stern's Review – Technical Annex to postscript



William Nordhaus,
University of Yale
Nobel 'Economics'
2018



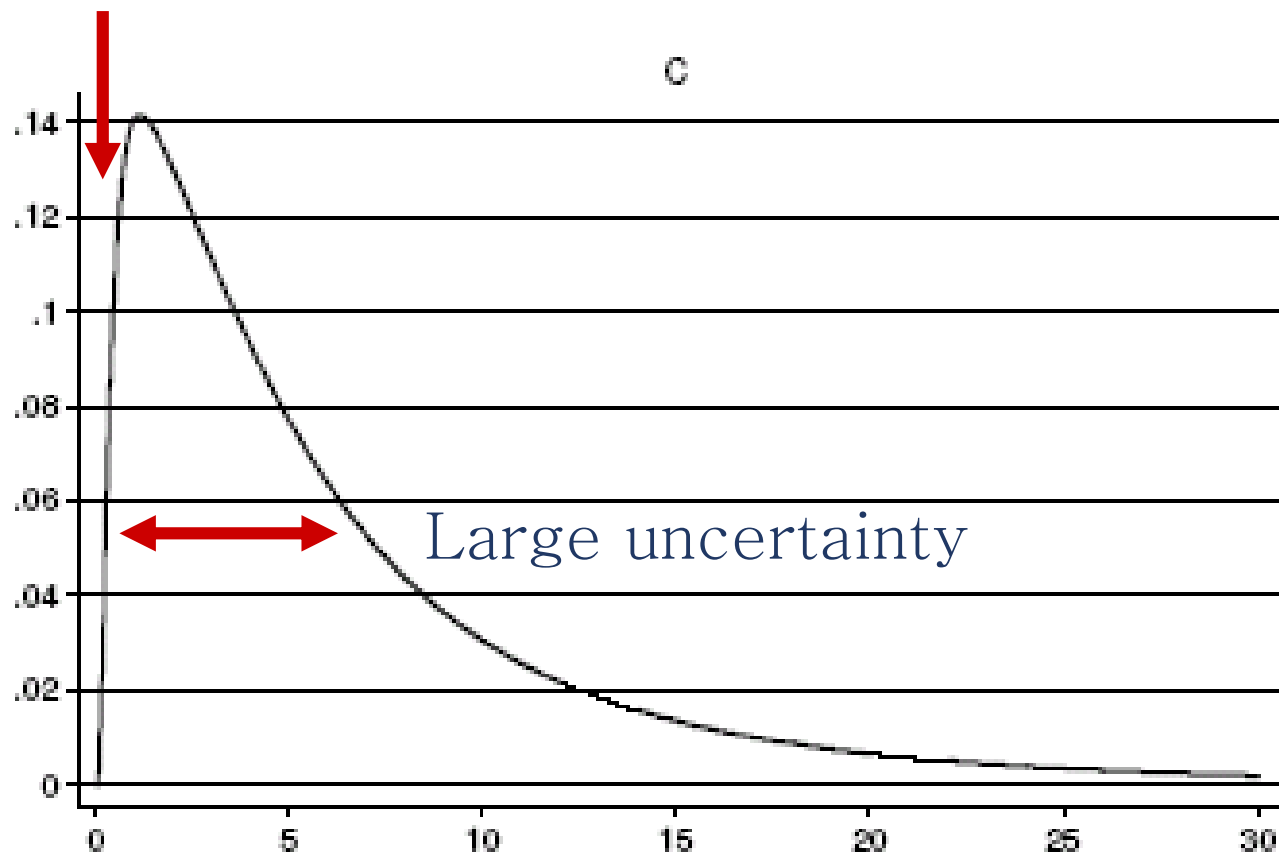
Nicholas Stern, London School
of Economics

Stern, N., Stern Review on the Economics of Climate Change. UK Government Economic Service, London, www.sternreview.org.uk.

Nordhaus W., Critical Assumptions in the Stern Review on Climate Change, SCIENCE, 317, 201–202, (2007).

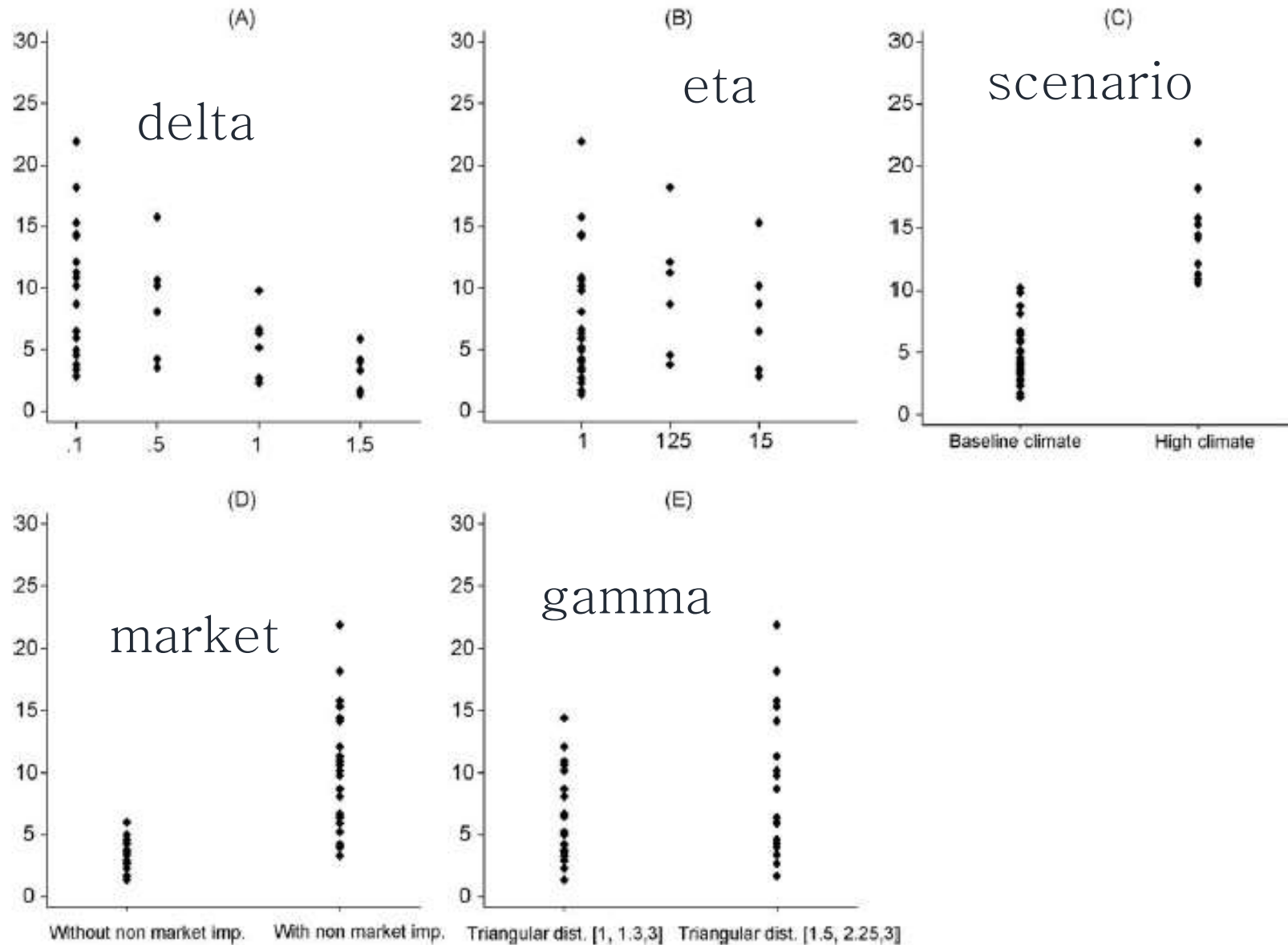
How was it done? A reverse engineering of the analysis

Missing points



% loss in GDP per capita

Sensitivity analysis here (by reverse engineering)



Why sensitivity analysis?

It allows interesting discoveries

J. R. Statist. Soc. A (2013)
176, Part 3, pp. 609–634

Ratings and rankings: voodoo or science?

Paolo Paruolo

University of Insubria, Varese, Italy

and Michaela Saisana and Andrea Saltelli

European Commission, Ispra, Italy

Why sensitivity
analysis

University rankings such as
ARWU and THES are
technically unsound

Ratings and rankings: voodoo or science?

Paolo Paruolo

University of Insubria, Varese, Italy

and Michaela Saisana and Andrea Saltelli

European Commission, Ispra, Italy

~~THE WORLD
UNIVERSITY
RANKINGS~~

Why sensitivity
analysis

Geophysical Research Letters / Volume 47, Issue 8

Research Letter

 Open Access



Current Models Underestimate Future Irrigated Areas

A. Puy✉, S. Lo Piano, A. Saltelli

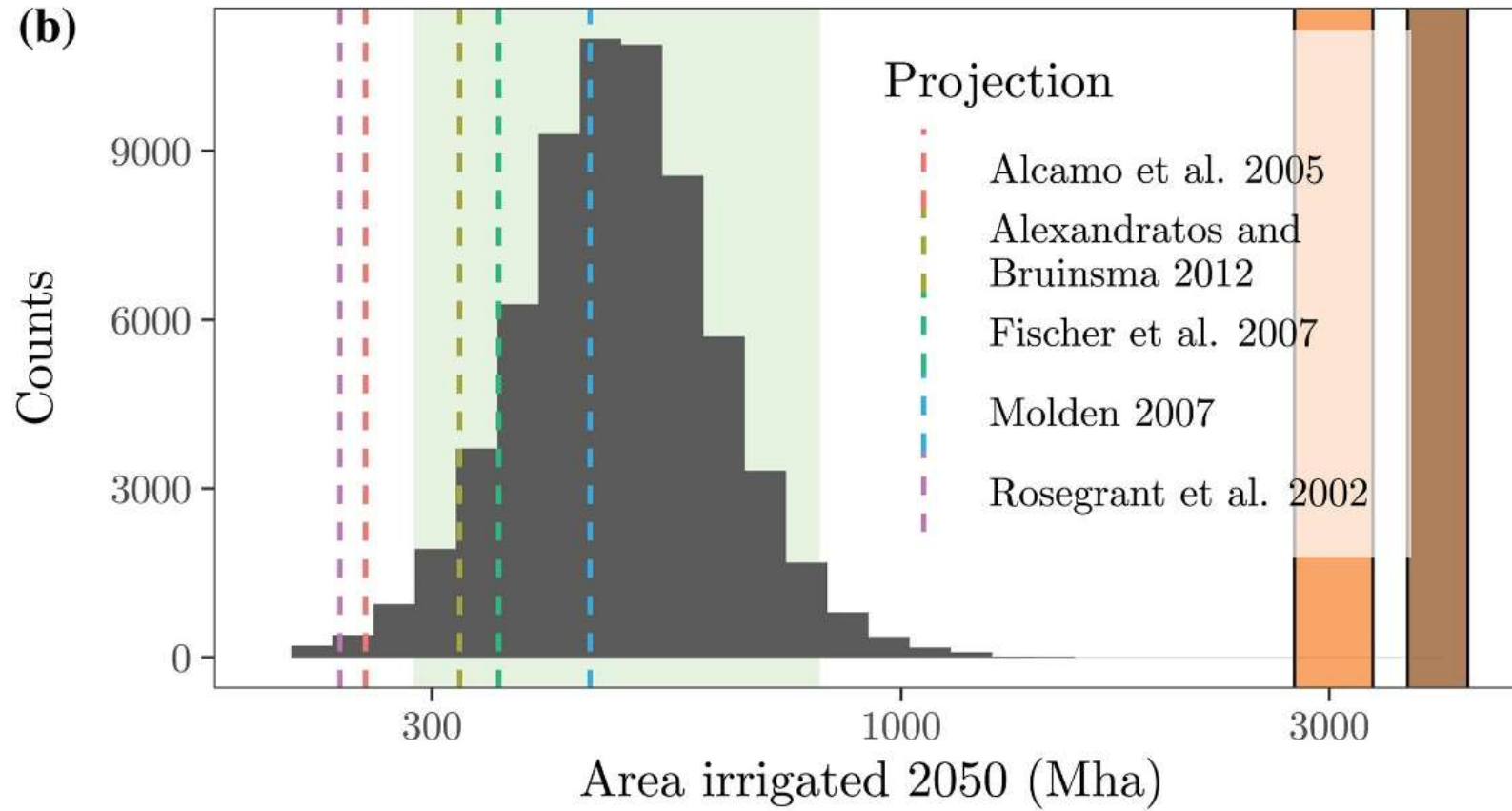
First published: 17 April 2020

<https://doi.org/10.1029/2020GL087360>

Citations: 2

Why sensitivity
analysis

(b)



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Current Models Underestimate Future Irrigated Areas

A. Puy , S. Lo Piano, A. Saltelli

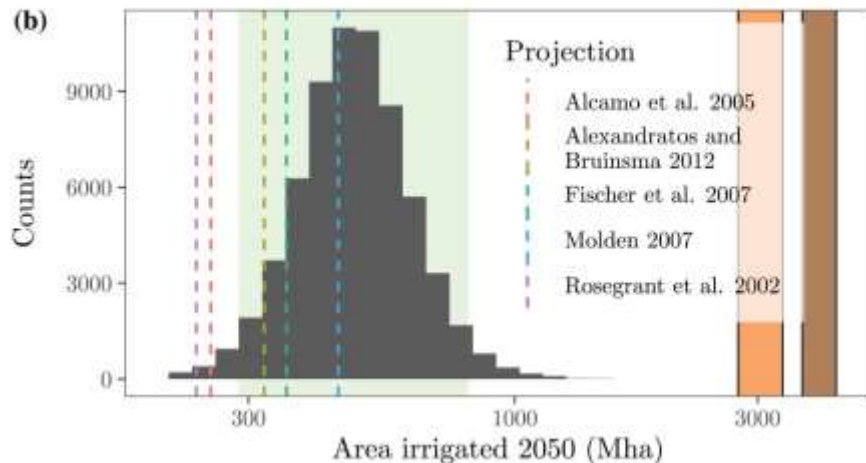
First published: 17 April 2020

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Citations: 2

Why sensitivity
analysis

Predictions underestimate the potential extension of irrigation ... uncertainty is mostly irreducible as it is largely caused by either population-related parameters or the assumptions behind the model design



Geophysical Research Letters / Volume 47, Issue 8

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Current Models Underestimate Future Irrigated Areas

A. Puy✉, S. Lo Piano, A. Saltelli

First published: 17 April 2020

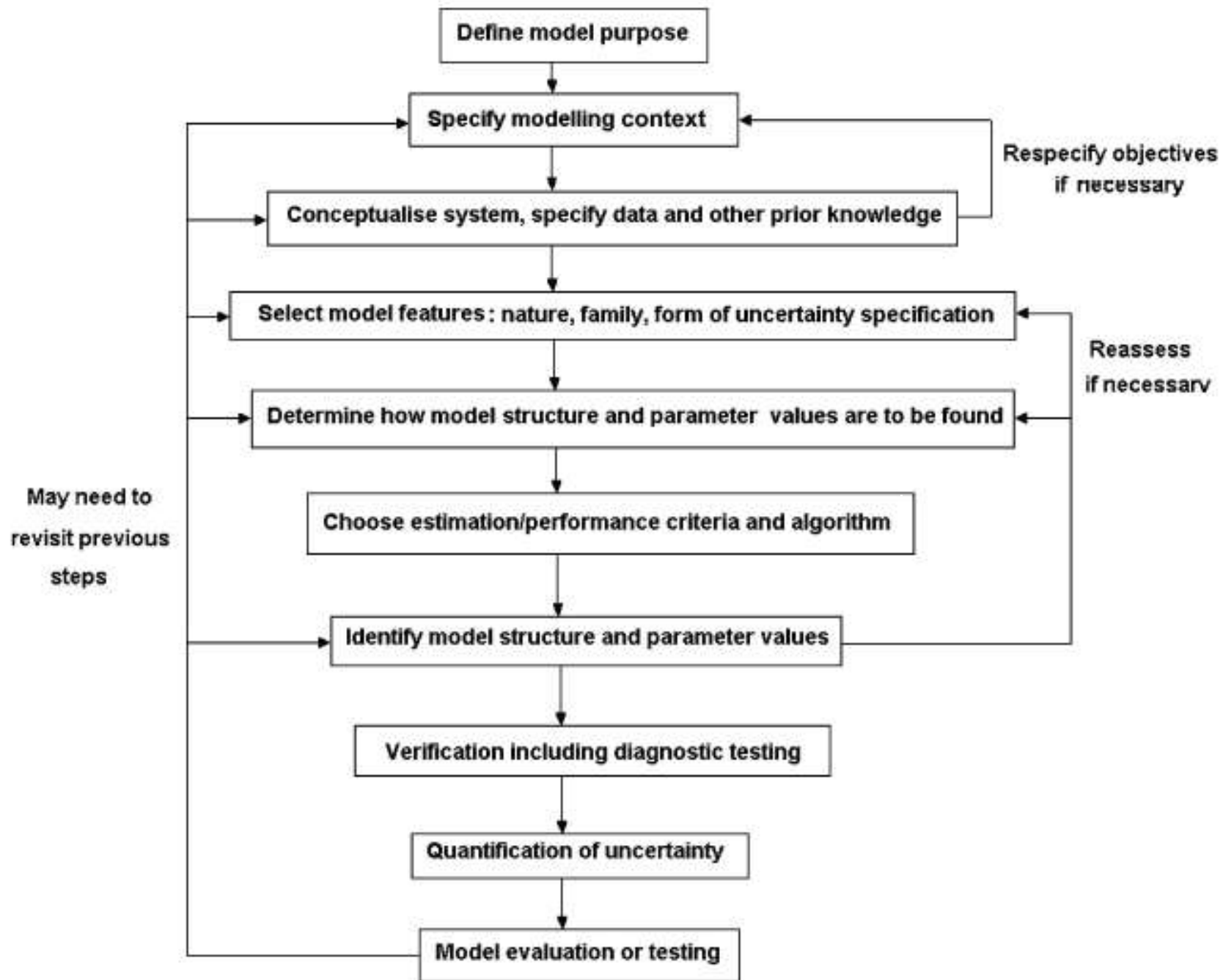
<https://doi.org/10.1029/2020GL087360>

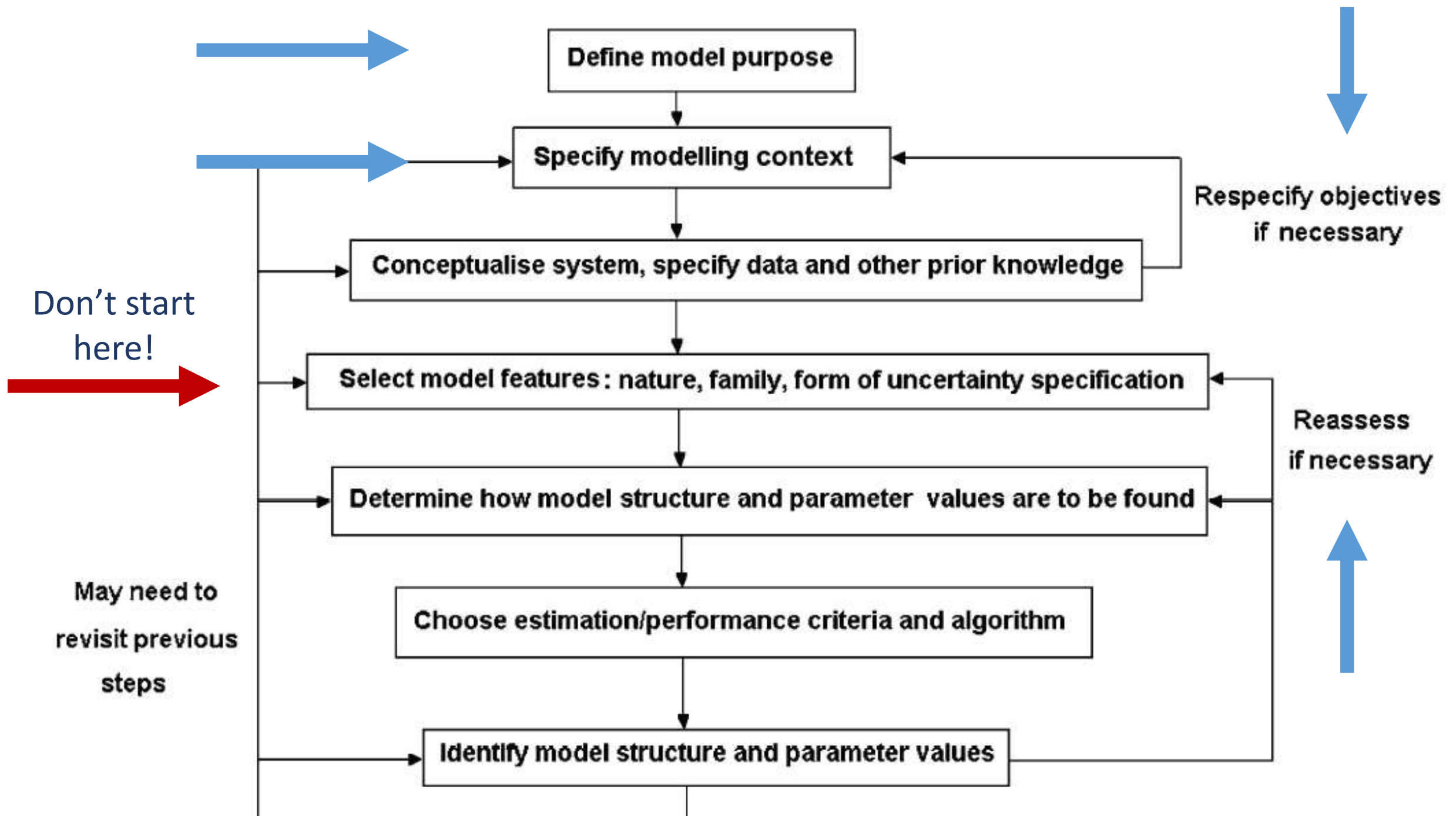
Citations: 2

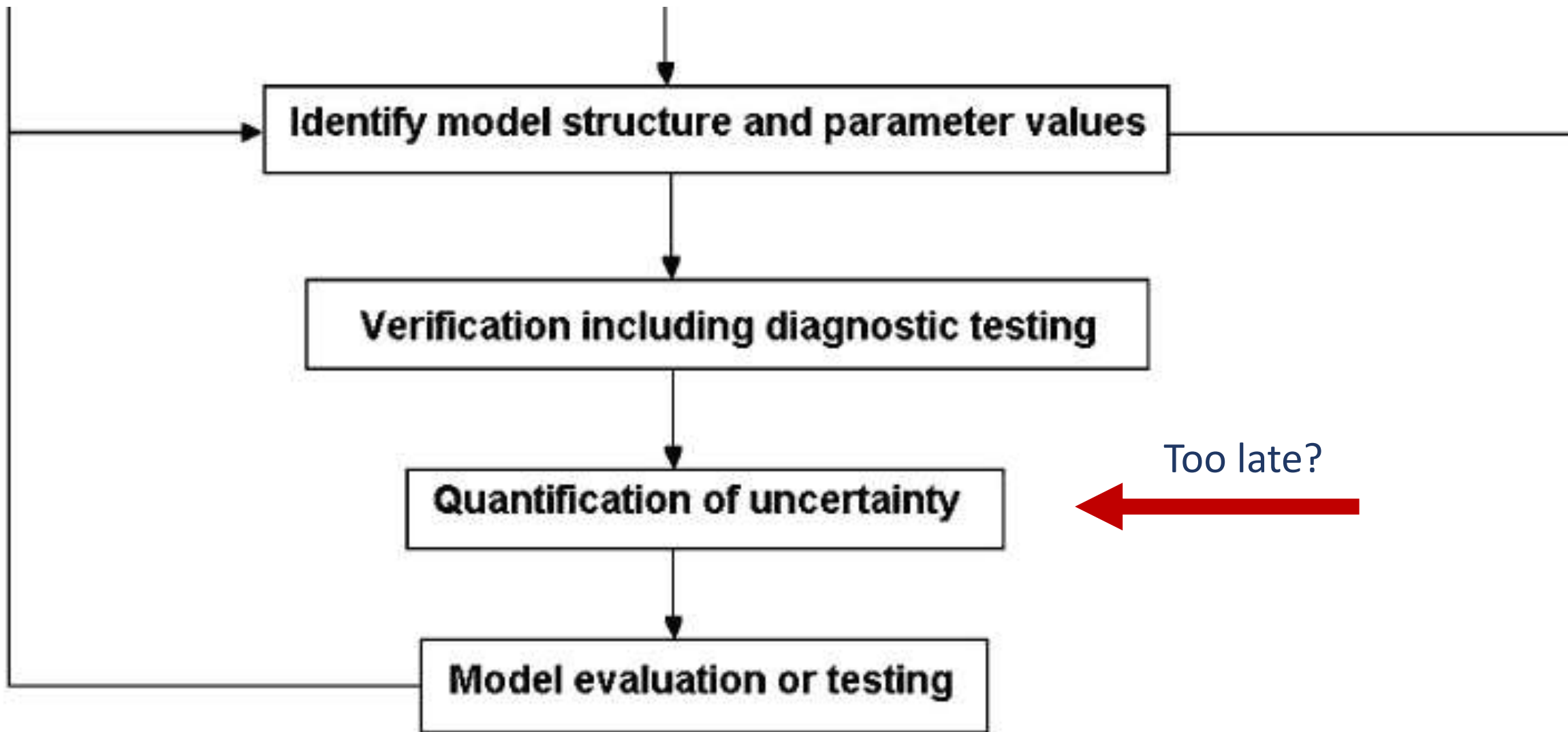
Why sensitivity analysis

A 10 points participatory checklist (Jakeman et al. 2006)

Jakeman, A. J., Letcher, R. A., & Norton, J. P. (2006). Ten iterative steps in development and evaluation of environmental models,. *Environmental Modelling & Software*, 21(5), 602–614.







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.

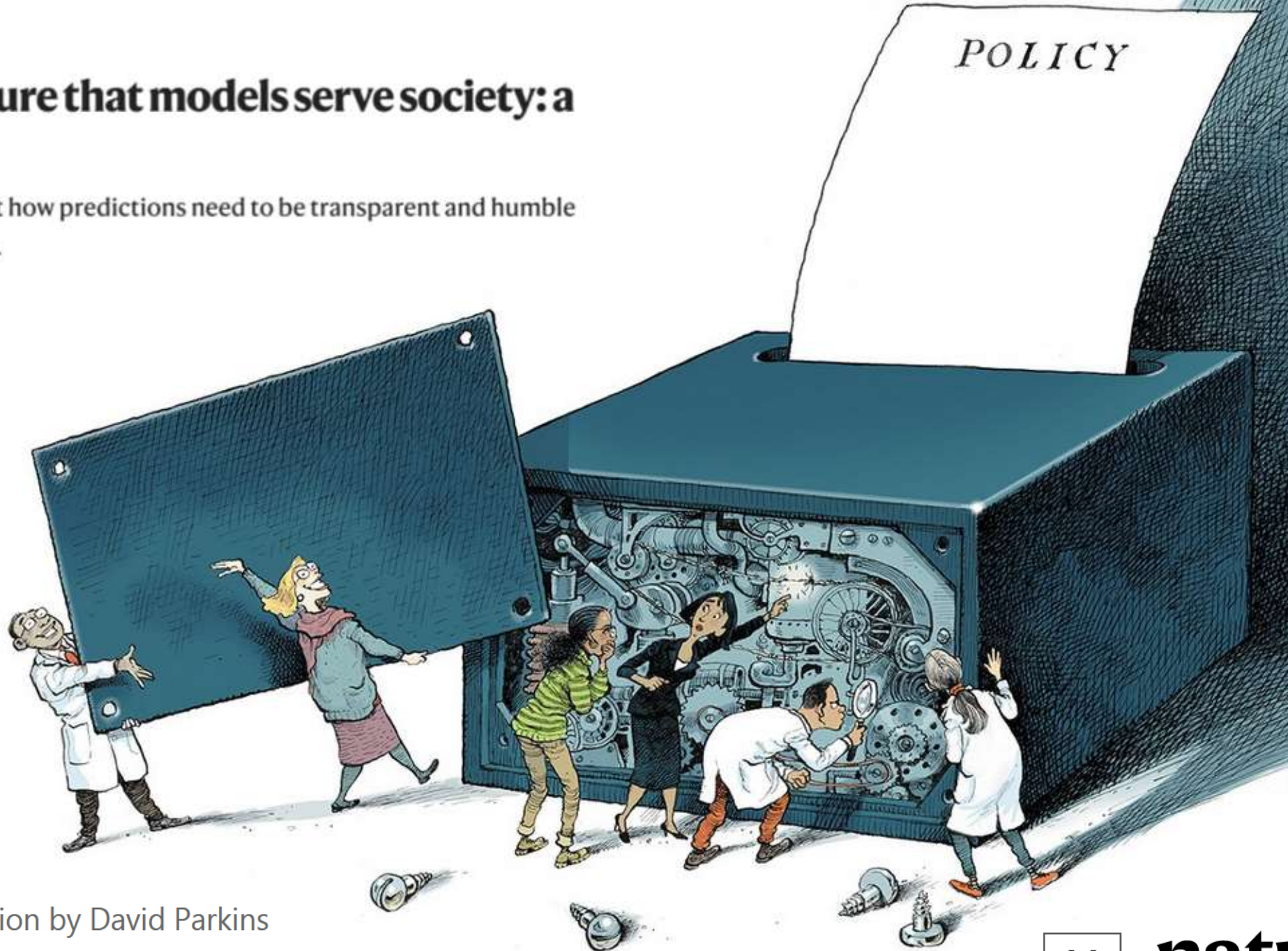


Illustration by David Parkins



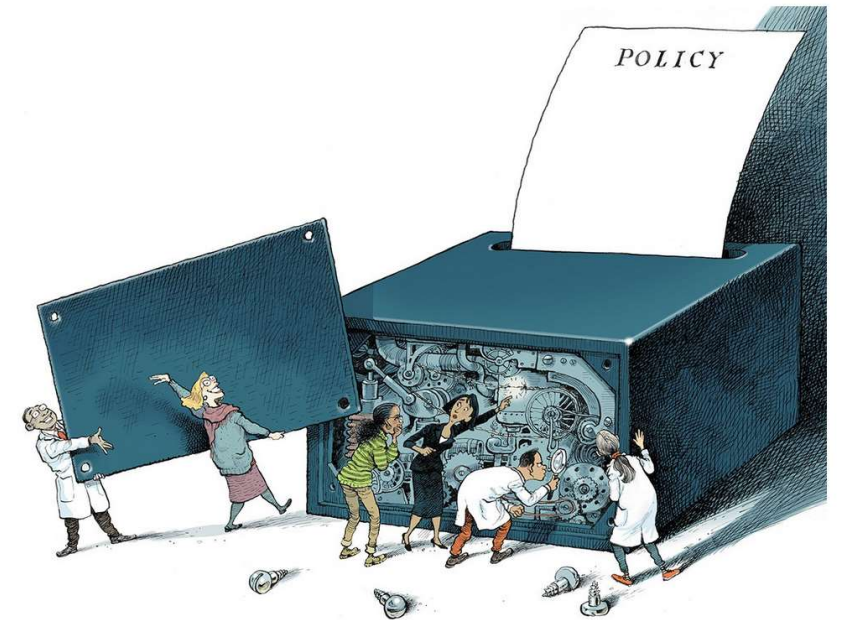
nature



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.

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



Mind the assumptions

Assess uncertainty and sensitivity



Mind the hubris

Complexity can be the enemy of relevance

Mind the framing

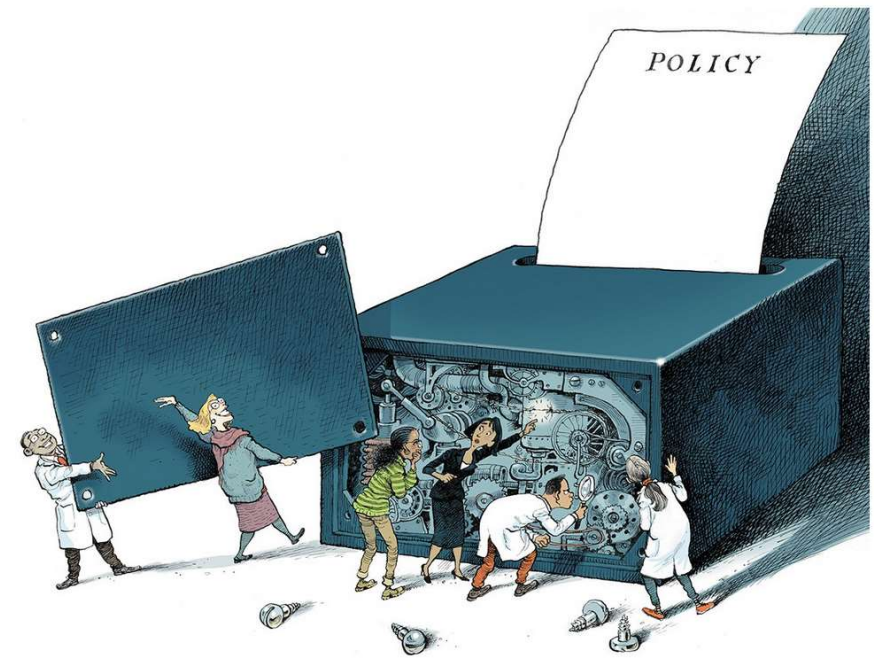
Match purpose and context

Mind the consequences

Quantification can backfire.

Mind the unknowns

Acknowledge ignorance



SUPPLEMENTARY INFORMATION

1. Additional information and references

>260 references

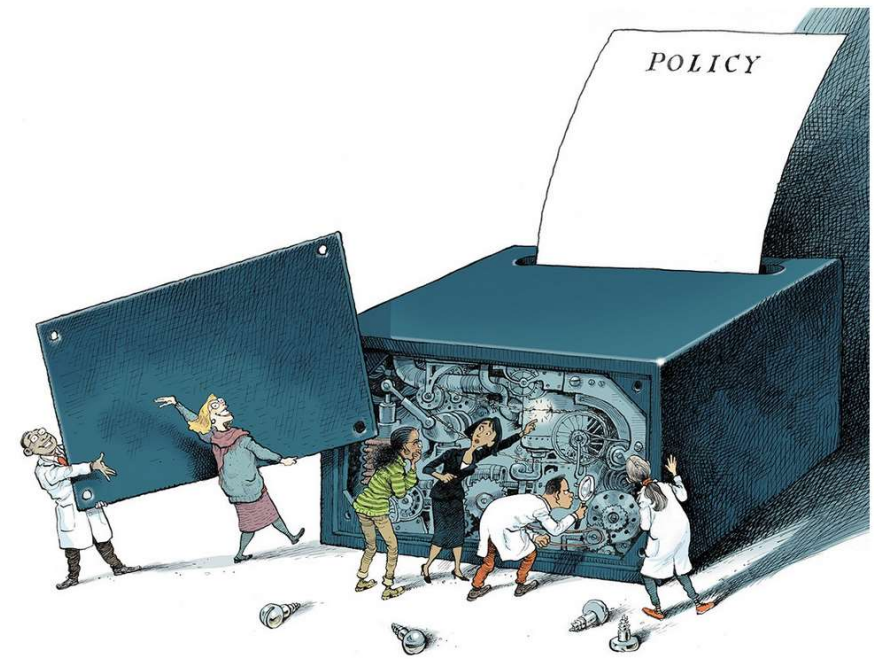
Mind the assumptions

Assess uncertainty and sensitivity



... assumptions that are reasonable in one situation can become nonsensical in another...

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

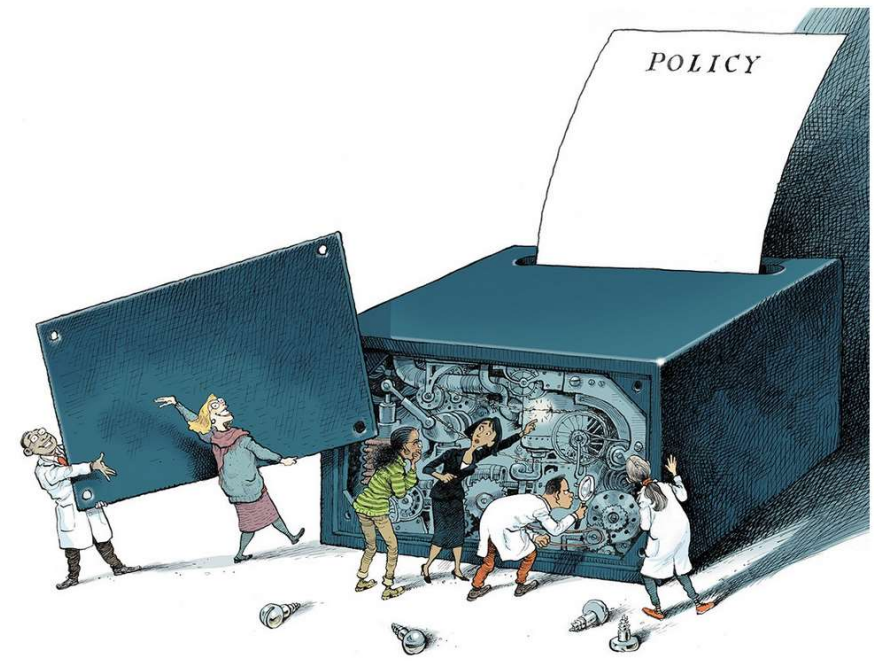


Mind the assumptions

Assess uncertainty and sensitivity



... to mitigate these issues:
perform global uncertainty and
sensitivity analyses ...

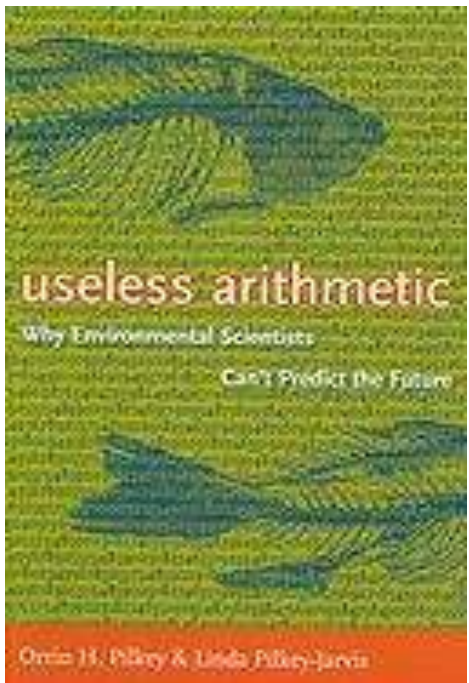


This often reveals that the uncertainty in
predictions is substantially larger than originally
asserted

Limits of sensitivity analysis

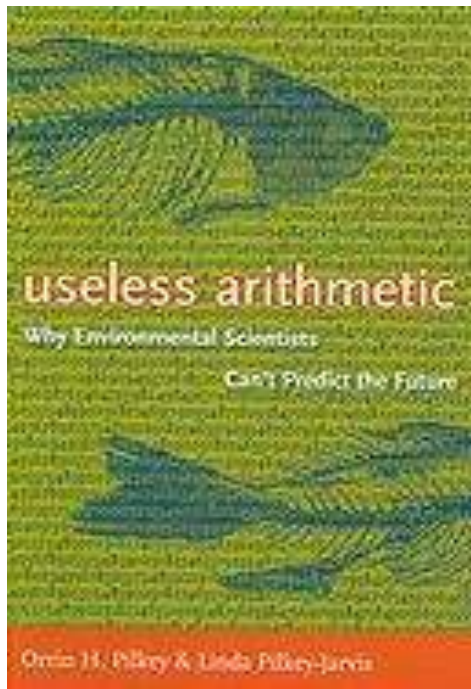


Orrin H.
Pilkey



Useless Arithmetic: Why Environmental Scientists Can't Predict the Future
by Orrin H. Pilkey and Linda Pilkey-Jarvis, Columbia University Press,
2009.

The map is not the
territory

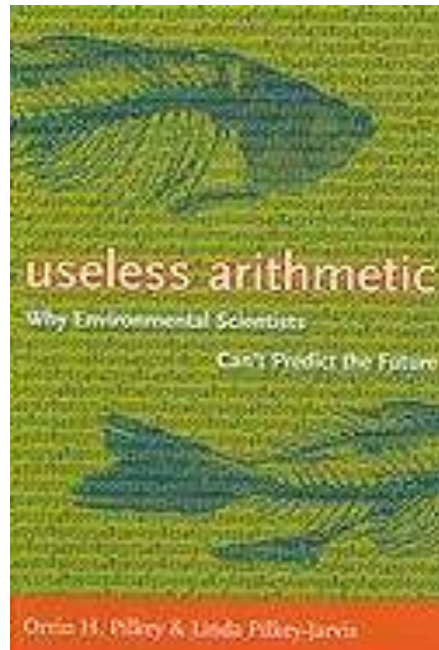


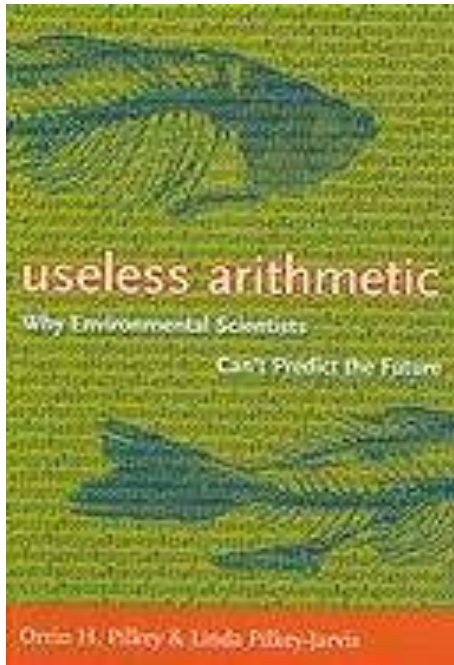
<<It is important, however, to recognize that the sensitivity of the parameter in the equation is what is being determined, not the sensitivity of the parameter in nature.

[...] If the model is wrong or if it is a poor representation of reality, determining the sensitivity of an individual parameter in the model is a meaningless pursuit.>>

One of the examples discussed concerns the **Yucca Mountain** repository for radioactive waste. TSPA model (for total system performance assessment) for safety analysis.

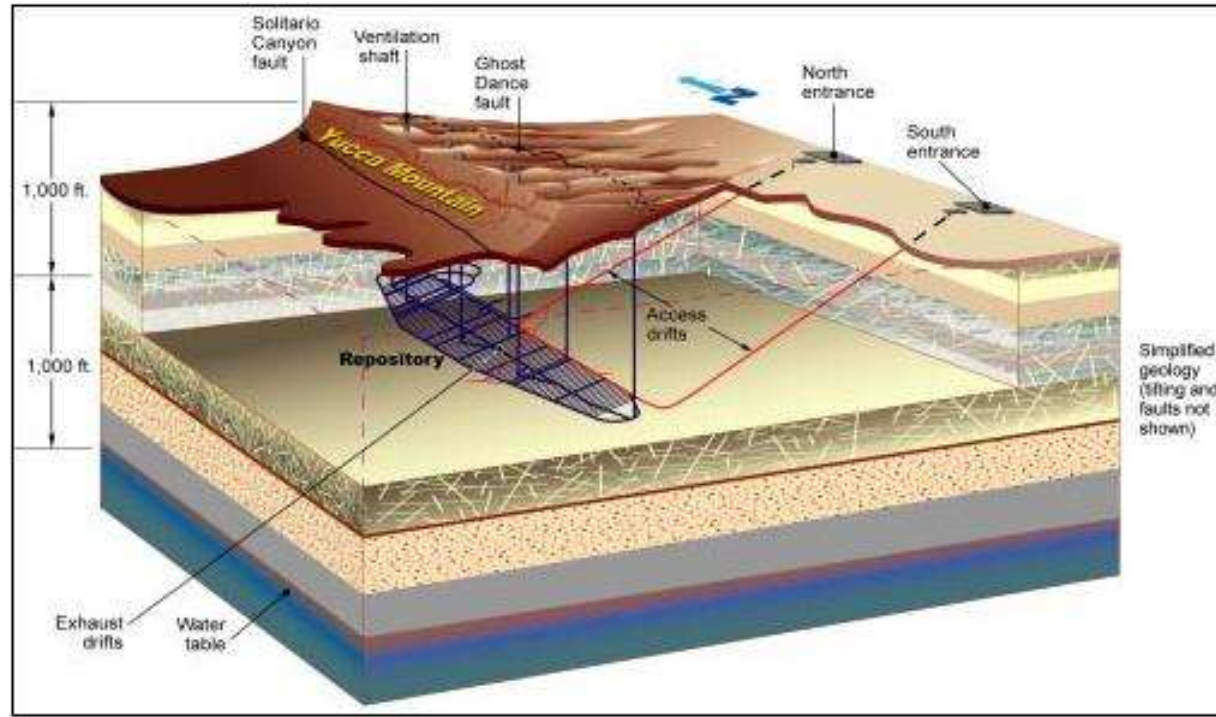
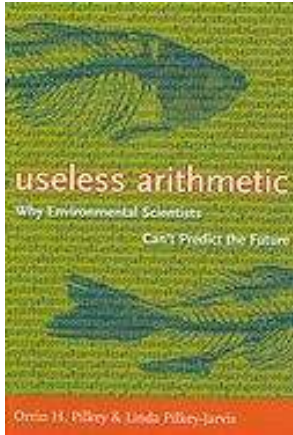
TSPA is Composed of 286 sub-models.





TSPA (like any other model) **relies on assumptions** → one is the low permeability of the geological formation → long time for the water to percolate from surface to disposal.



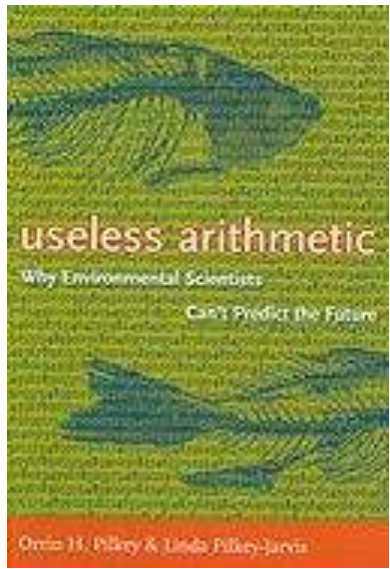


The confidence of the stakeholders in TSPA was not helped when evidence was produced which could lead to an upward revision of 4 orders of magnitude of this parameter
(the ^{36}Cl story)

Type III error in sensitivity: Examples:

In the case of TSPA (Yucca mountain) a range of 0.02 to 1 millimetre per year was used for percolation of flux rate.

→... SA useless if it is instead ~ 3,000 millimetres per year.



“Scientific mathematical modelling should involve constant efforts to falsify the model”

➔ Organized skepticism (as per CUDOS)

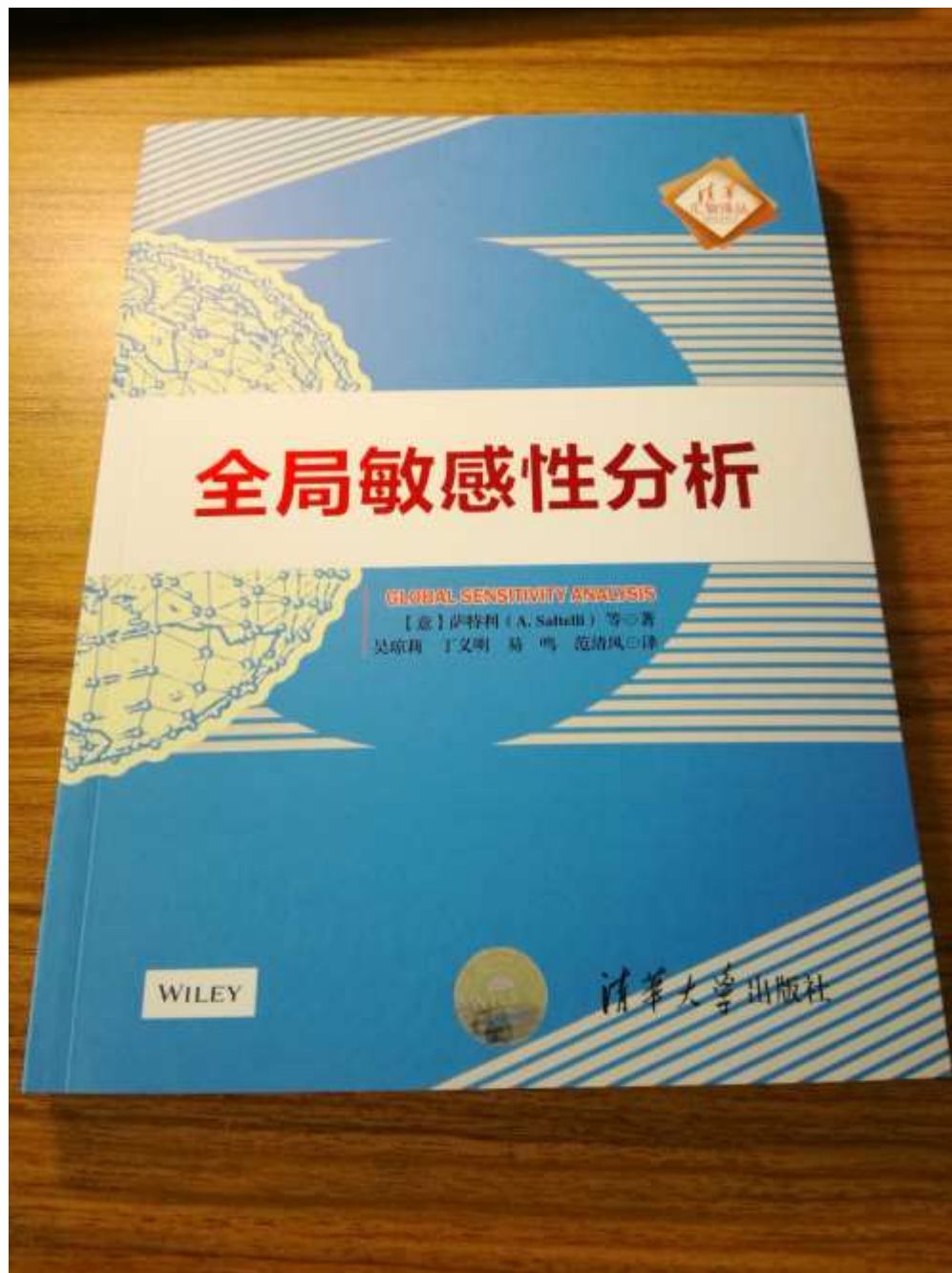
Where to study
sensitivity analysis?

A. Saltelli, M. Ratto,
T. Andres, F. Campolongo,
J. Cariboni, D. Gatelli,
M. Saisana, S. Tarantola

GLOBAL SENSITIVITY ANALYSIS

The Primer

 WILEY



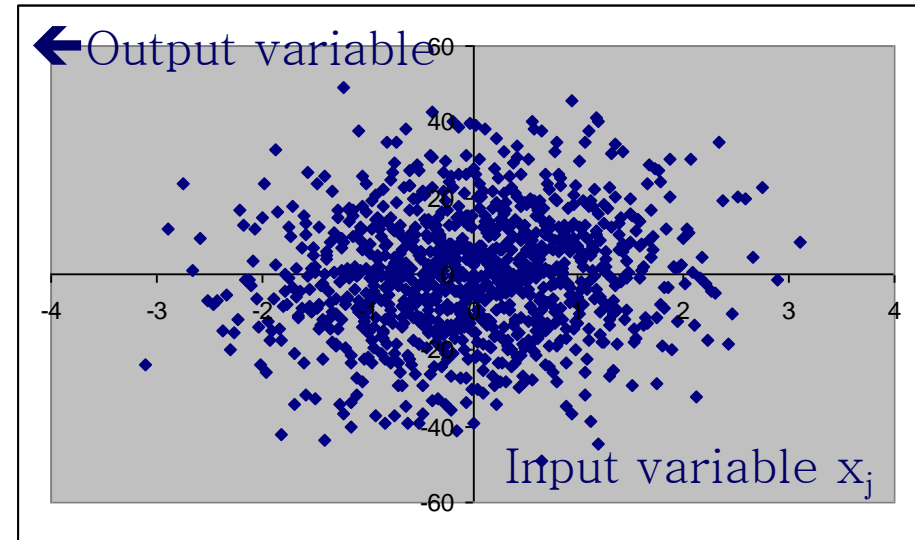
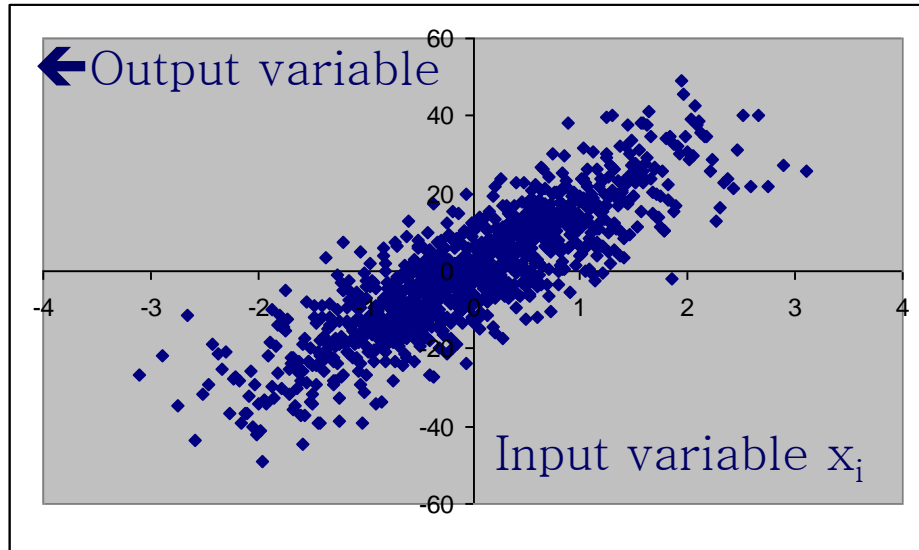


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Available for free at

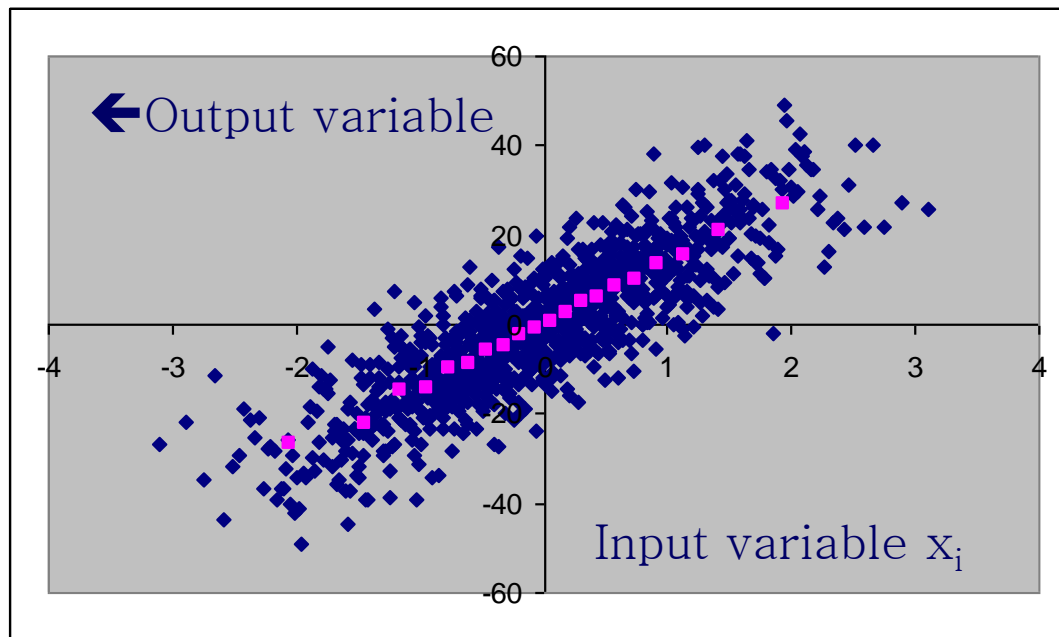
<http://www.andreasaltelli.eu>

How is it done in
practice?



Plotting the output as a function of two different input factors

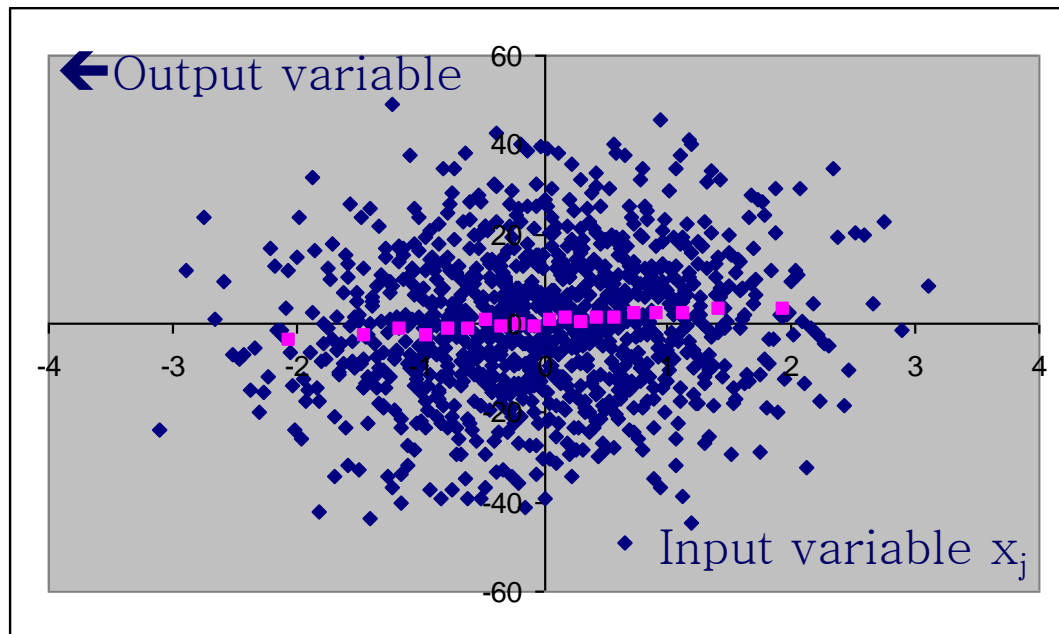
Which factor is more important?

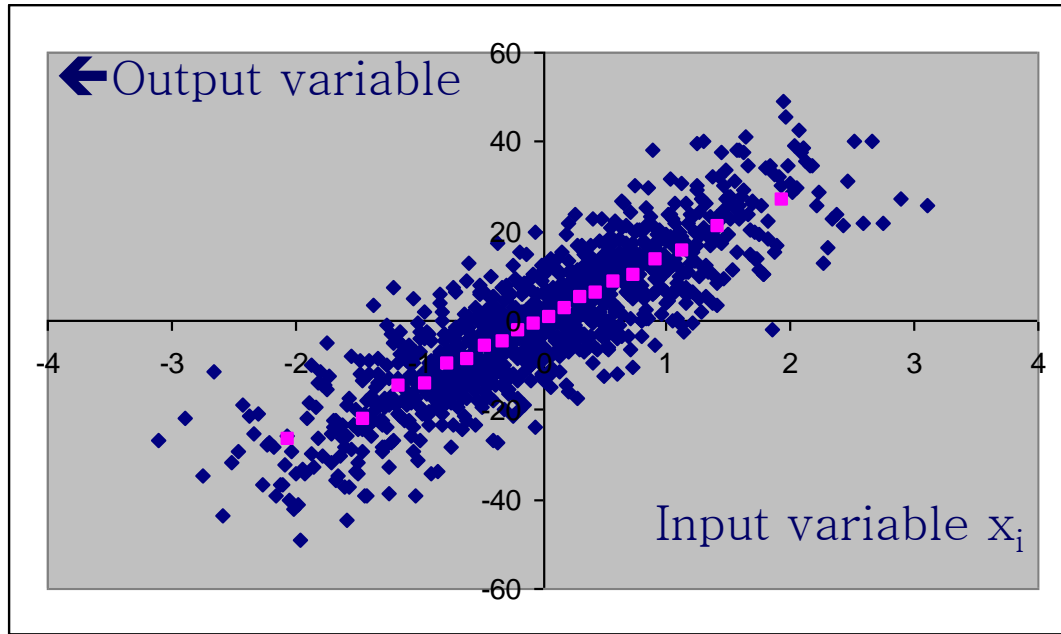


~1,000 blue points

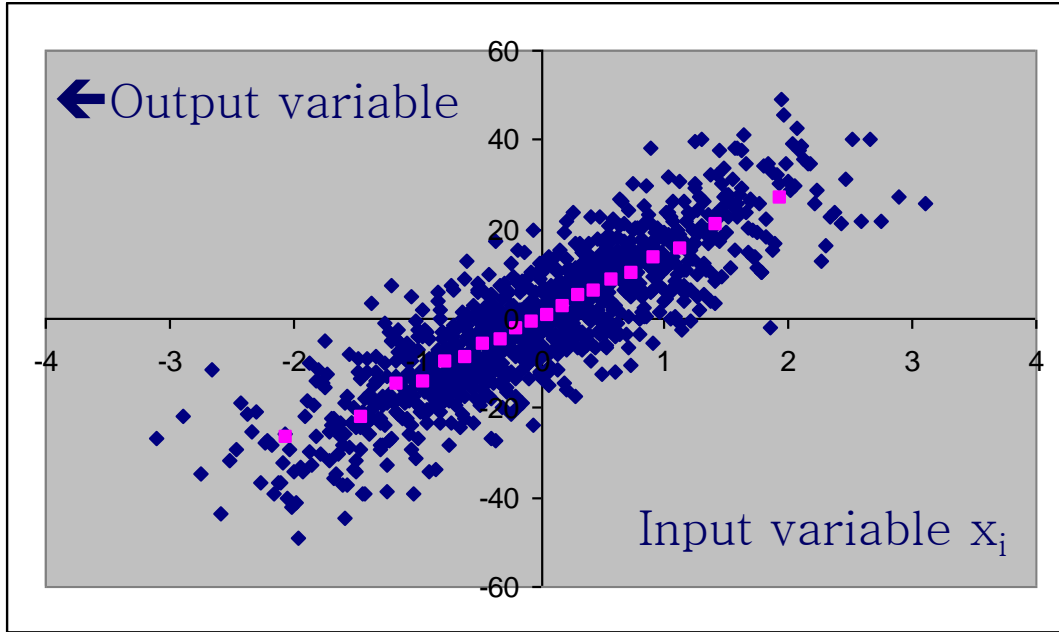
Divide them
in 20 bins of
~ 50 points

Compute the
bin's average
(pink dots)



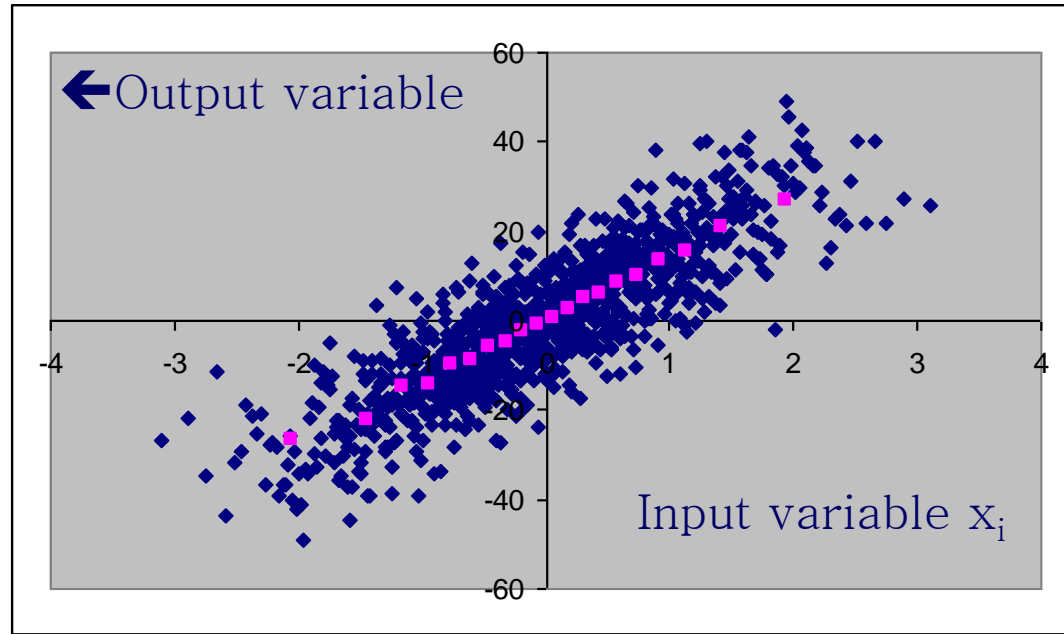


Each pink point is $\sim E_{\mathbf{x}_{\sim i}}(Y|X_i)$

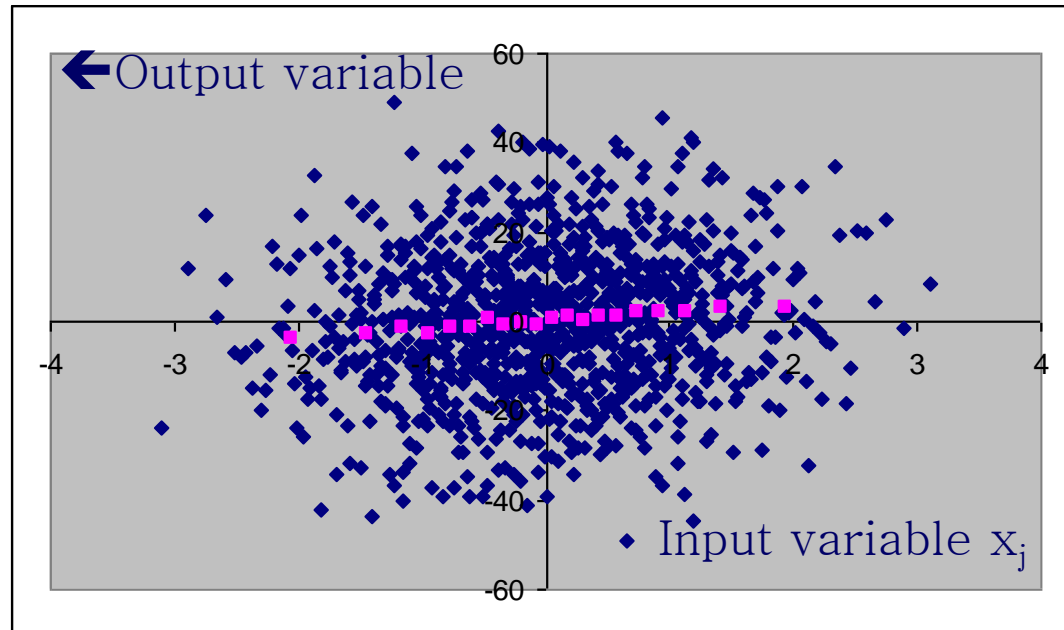


Take the variance of
the pink points one
obtains a sensitivity
measure

$$V_{X_i} \left(E_{\mathbf{X}_{\sim i}} (Y | X_i) \right)$$



Which factor
has the highest
 $V_{X_i} \left(E_{\mathbf{x}_{\sim i}} (Y | X_i) \right) ?$



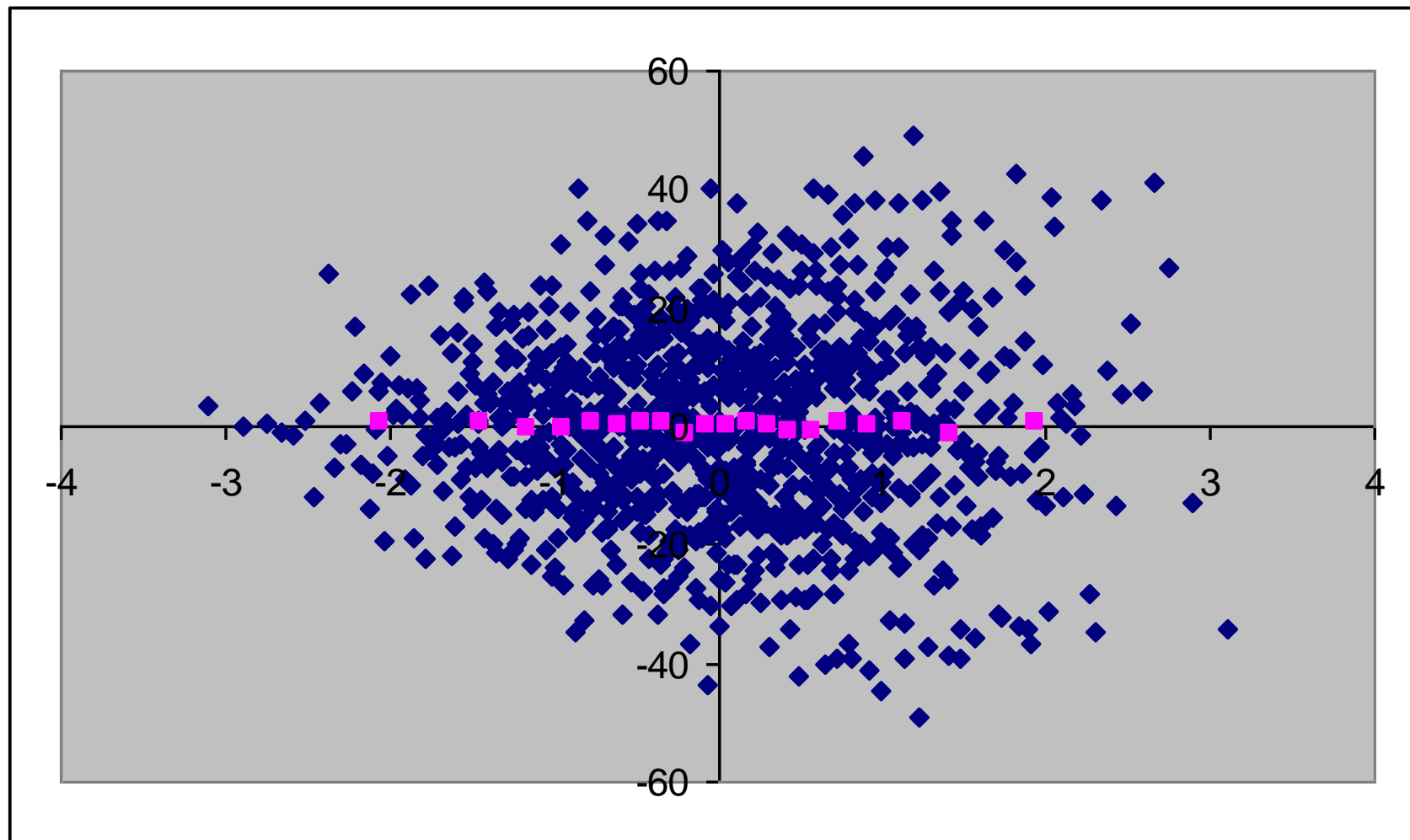
For additive models one can decompose the total variance as a sum of first order effects

$$\sum_i V_{X_i} \left(E_{\mathbf{X}_{\sim i}} (Y | X_i) \right) \approx V(Y)$$

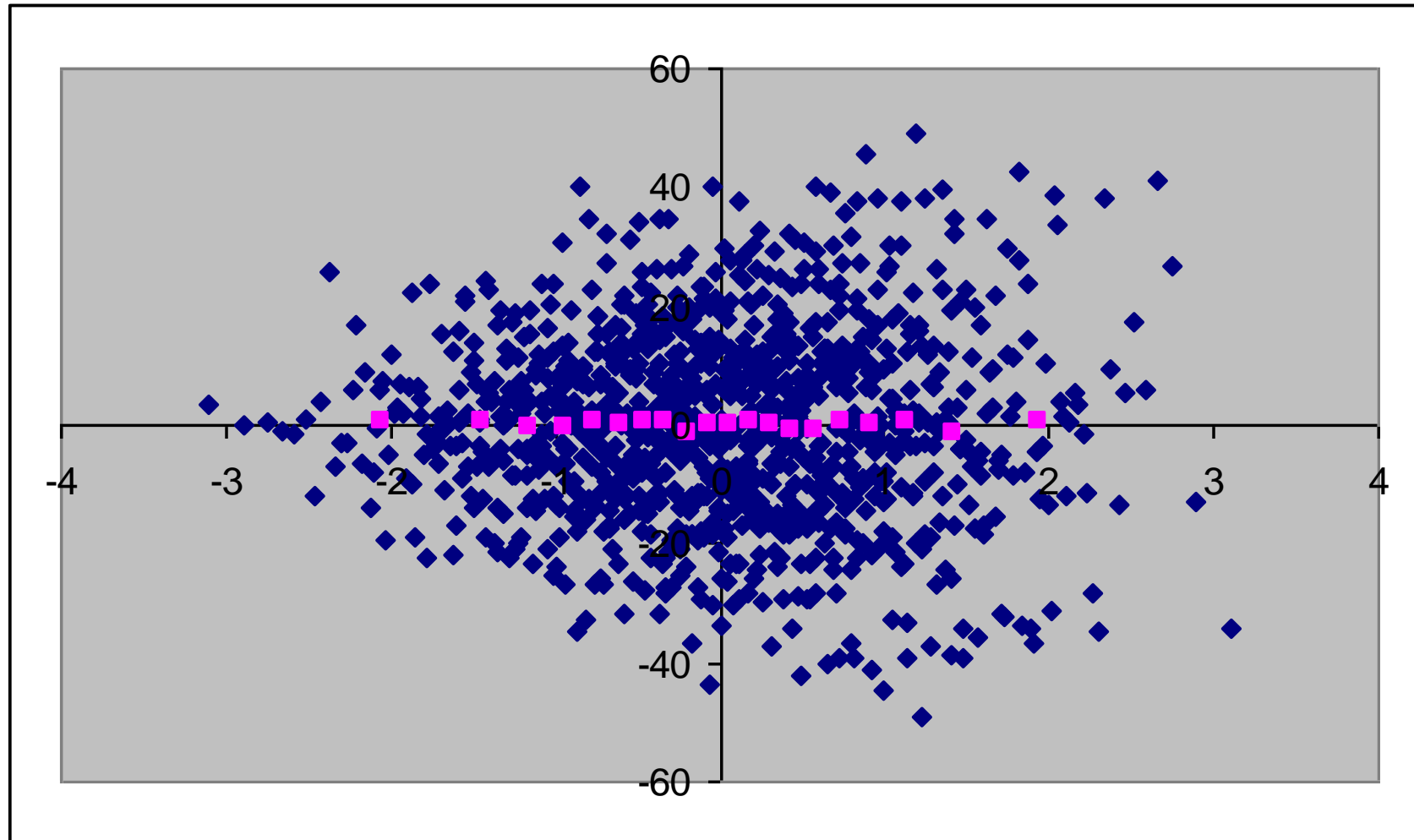
... which is also how additive models are defined

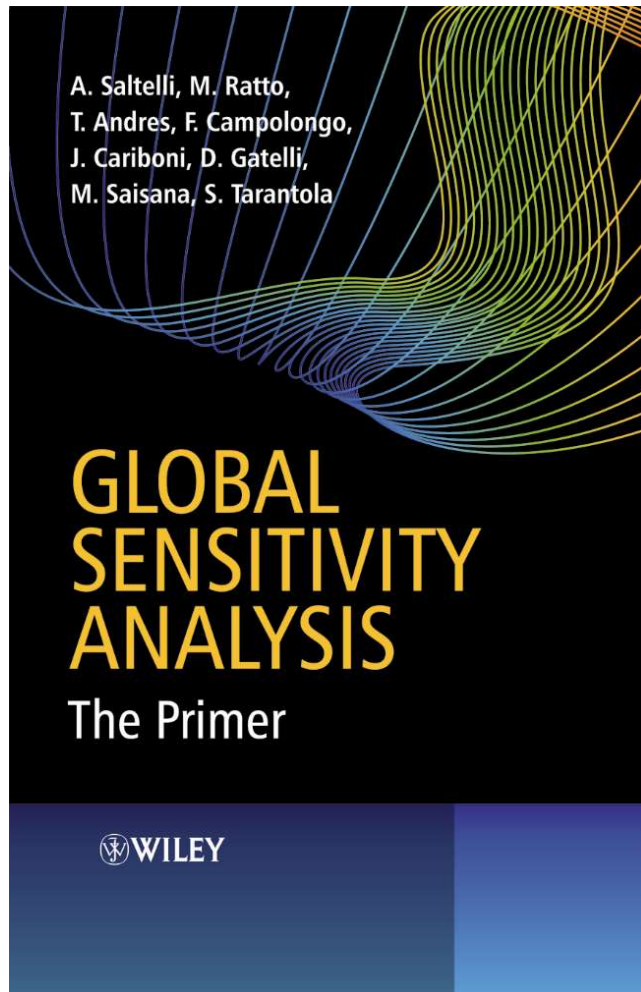
Non additive models

Is $S_i = 0$?



Is this factor non-important?





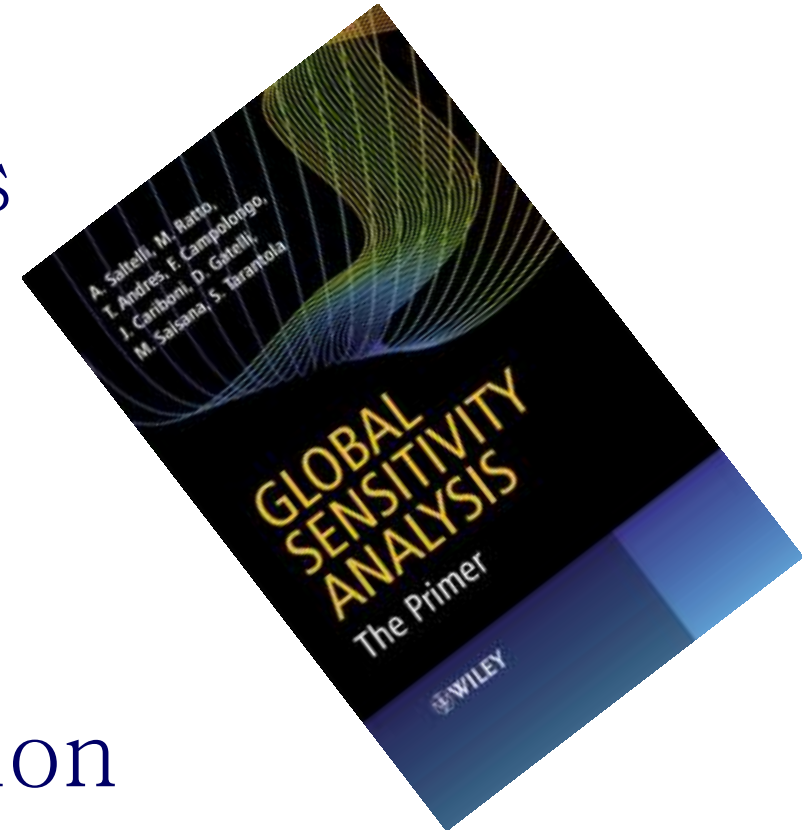
The theory of variance based sensitivity measures can cope ... with another measure we do not describe today ...

Plenty of code available in MATLAB, R and Phyton

Why using variance-based
sensitivity analysis methods

Advantages with variance based methods:

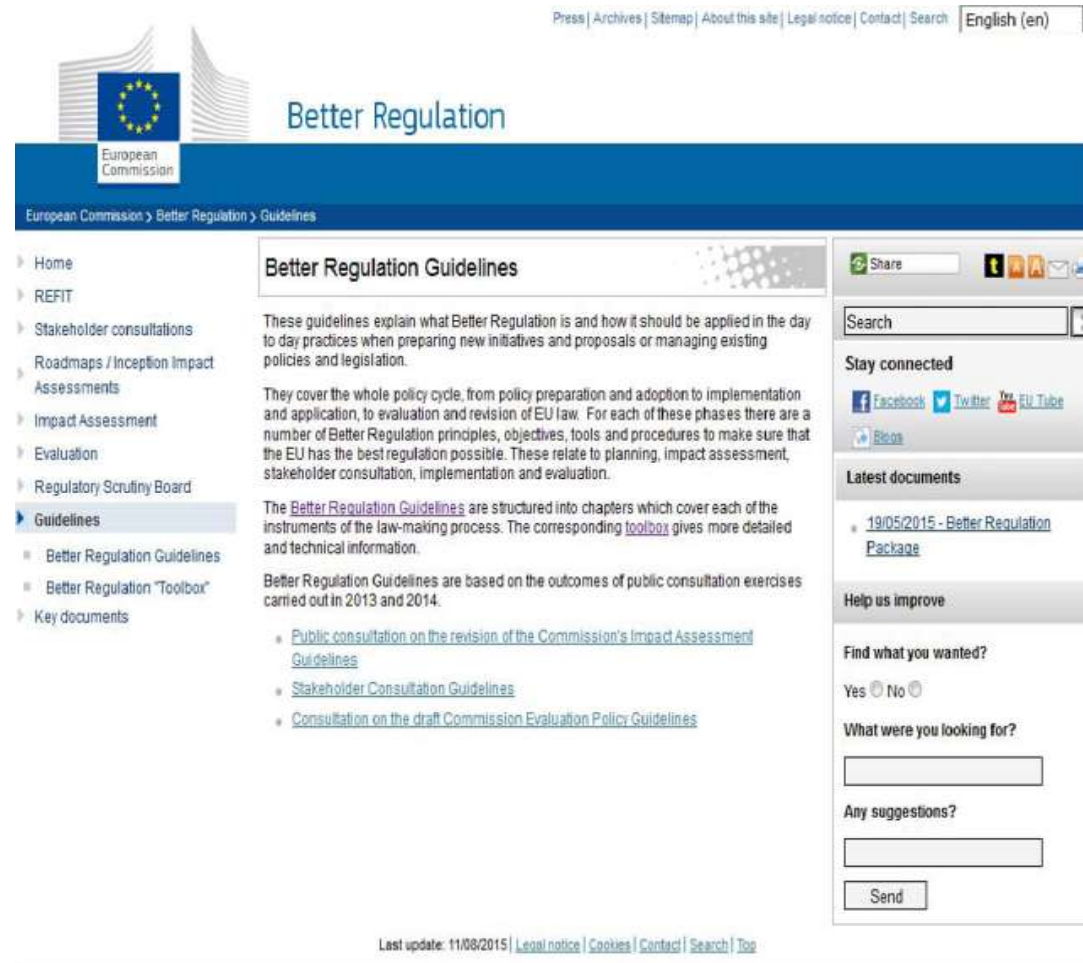
- graphic interpretation scatterplots
- statistical interpretation
- expressed plain English
- working with sets
- relation to settings such as factor fixing and factor prioritization



Secrets of sensitivity analysis

Why should one
ever run a model
just once?

EC impact assessment guidelines: sensitivity analysis & auditing



http://ec.europa.eu/smart-regulation/guidelines/docs/br_toolbox_en.pdf

First secret: The most important question is the question.

Or: sensitivity analysis is not “run” on a model but on a model once applied to a question

Second secret: Sensitivity analysis should not
be used to hide assumptions
[it often is]



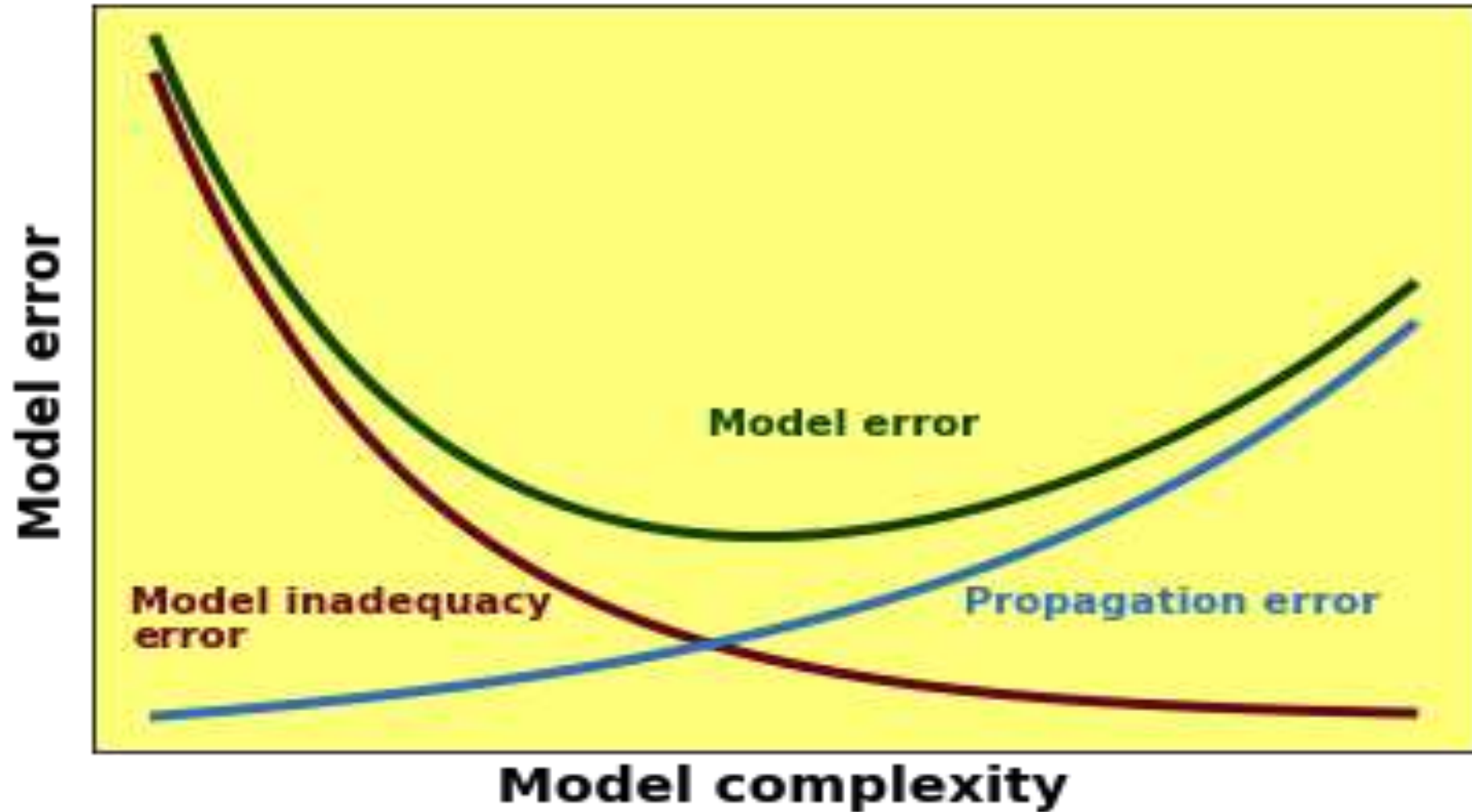
Third secret: If sensitivity analysis shows that a question cannot be answered by the model one should find another question or model

[Often the love for one's own model prevails]

Fourth (badly kept) secret:
There is always one more bug!
=Lubarsky's Law of Cybernetic Entomology

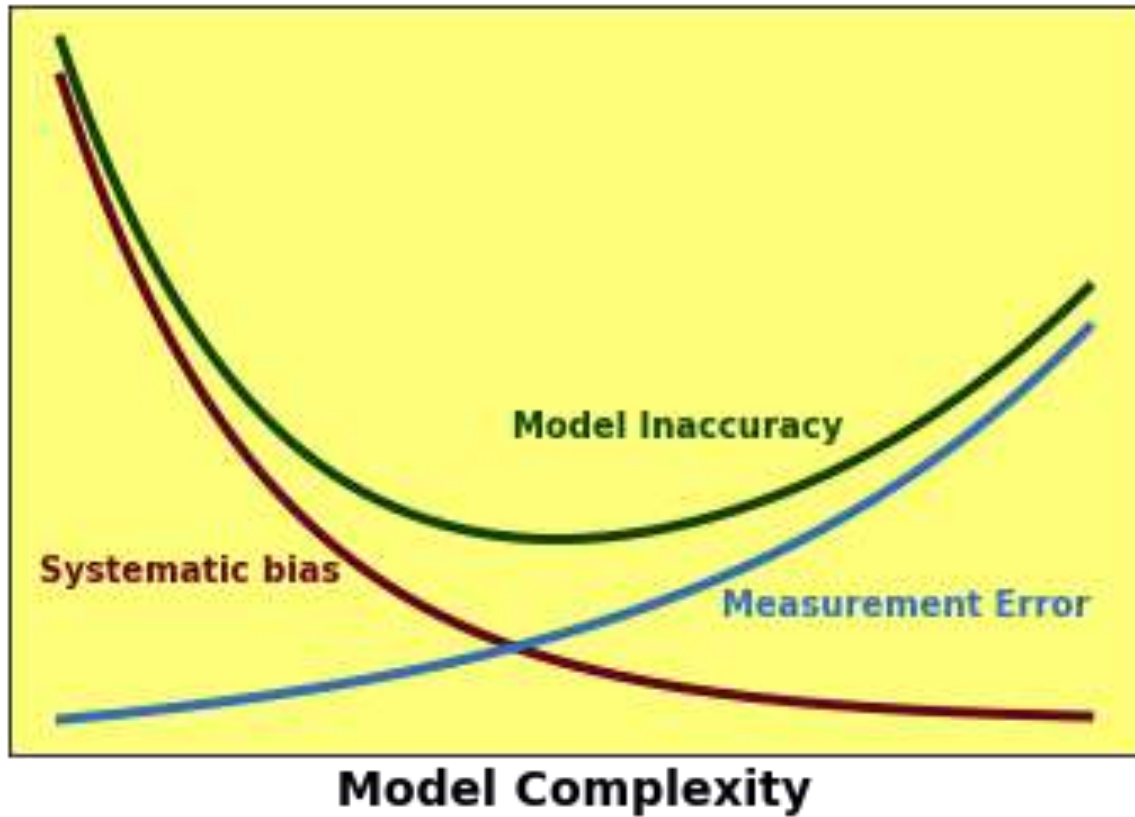


Fifth secret: use SA to calibrate complexity



Presented as ‘Conjecture by O’Neill’

In M. G. Turner and R. H. Gardner,
“Introduction to Models” in Landscape
Ecology in Theory and Practice, New
York, NY: Springer New York, 2015, pp.
63–95.



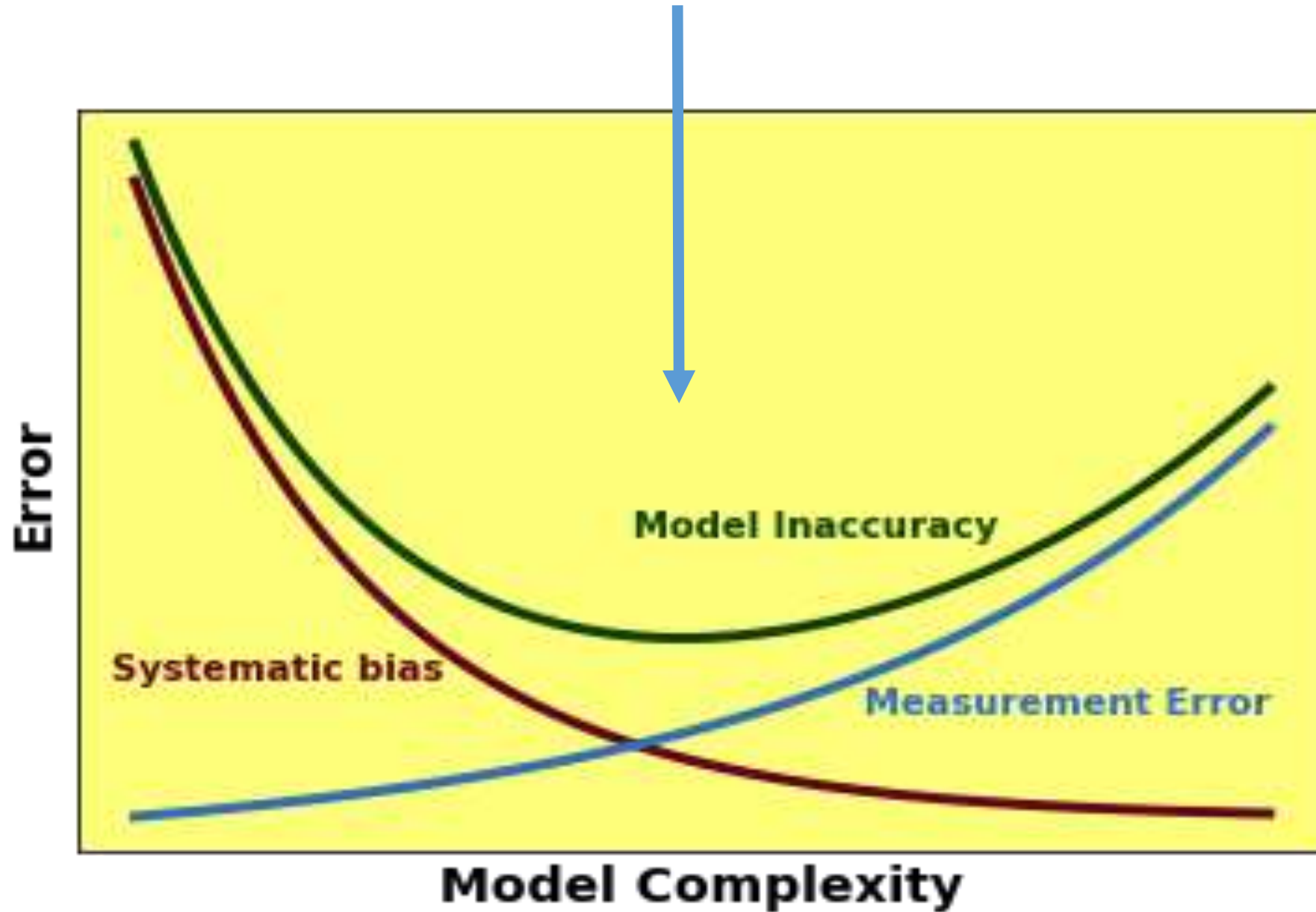


Lofti Aliasker Zadeh

Also known as Zadeh's principle of incompatibility, whereby as complexity increases “precision and significance (or relevance) become almost mutually exclusive characteristics”

L. Zadeh, “Outline of a New Approach to the Analysis of Complex Systems and Decision Processes,” *IEEE Trans. Syst. Man. Cybern.*, vol. 3, no. 1, pp. 28–44, 1973.

SA can help to find this minimum





Comment

Open Access

Published: 27 August 2019

A short comment on statistical versus mathematical modelling

Andrea Saltelli 

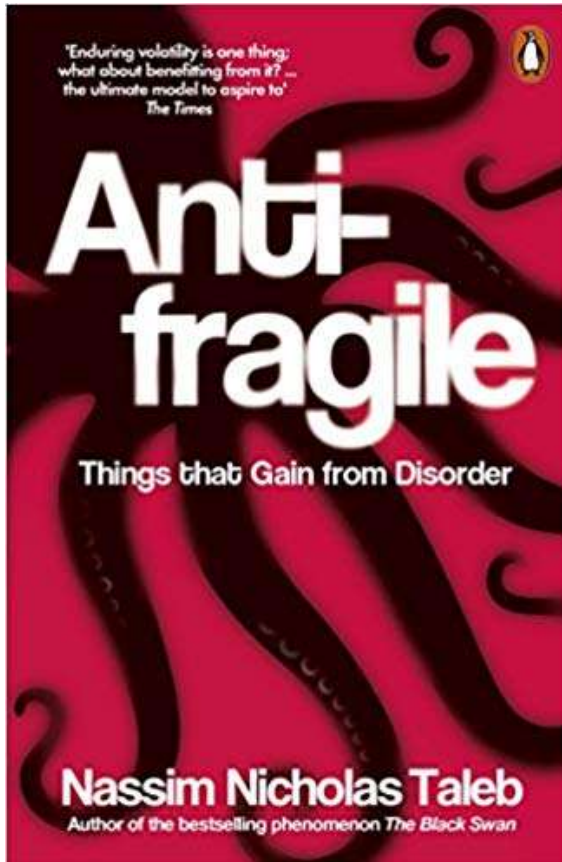
Sixth secret:

With SA it is easier to disprove than to prove; use
SA 'via negativa':

Doing the right thing

or

Avoiding something wrong?



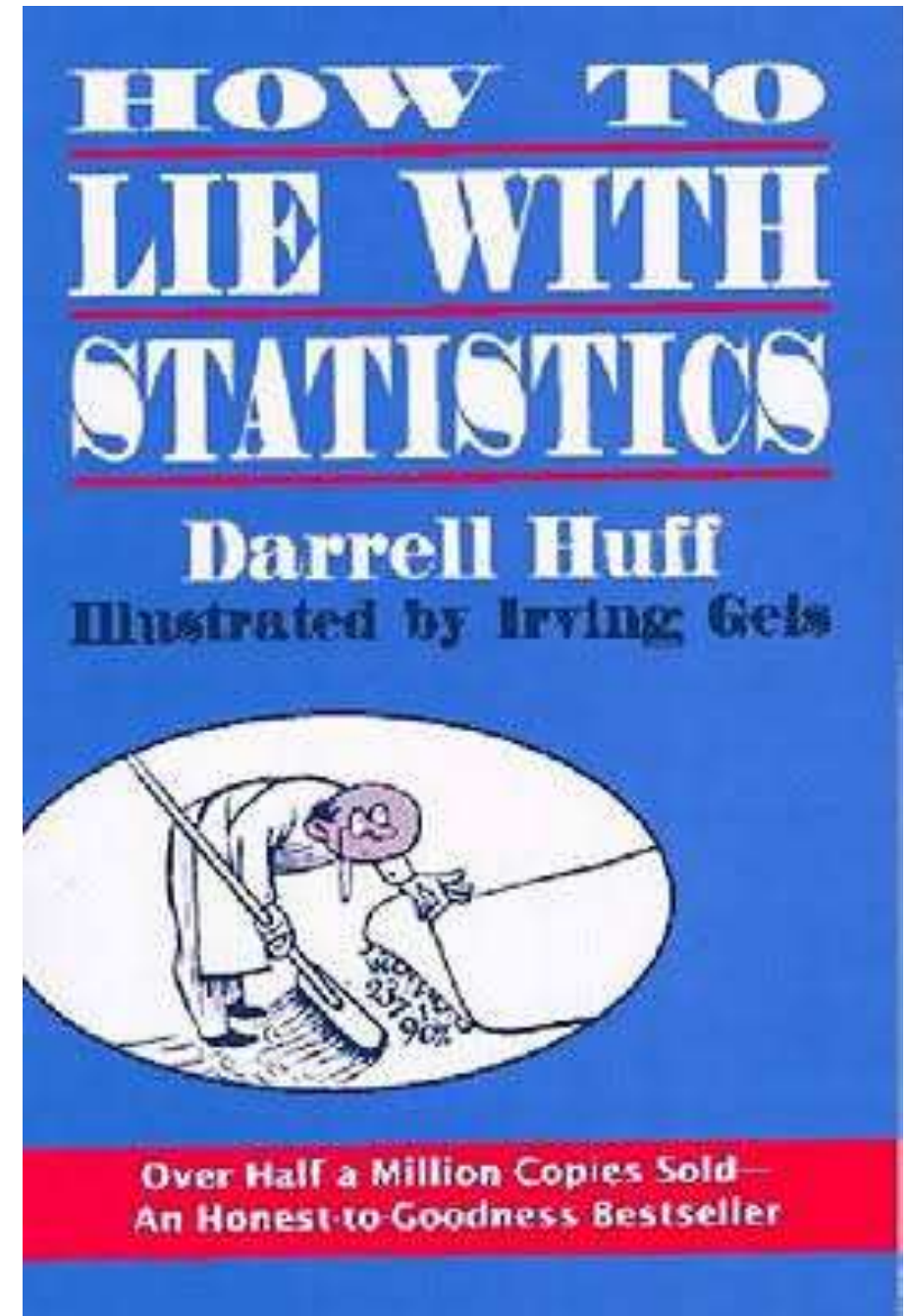
And of course please don't run a sensitivity analysis where each factors has a 5% uncertainty





Why?

Can we say that one lies with sensitivity analysis as one can lie with statistics?



Limit of SA: Often no SA (SA
conflated with UA e.g. in economics) or
one-factor-at-a-time SA

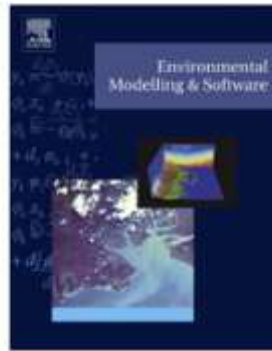
Why is OAT (one-factor-at-a-time) SA so bad?



Contents lists available at ScienceDirect

Environmental Modelling & Software

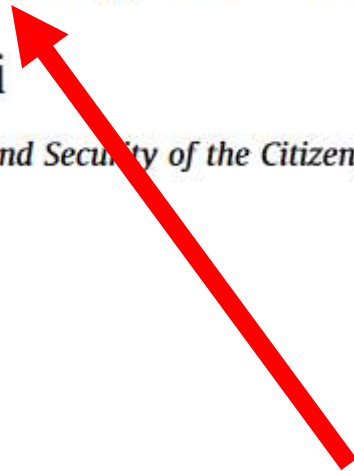
journal homepage: www.elsevier.com/locate/envsoft



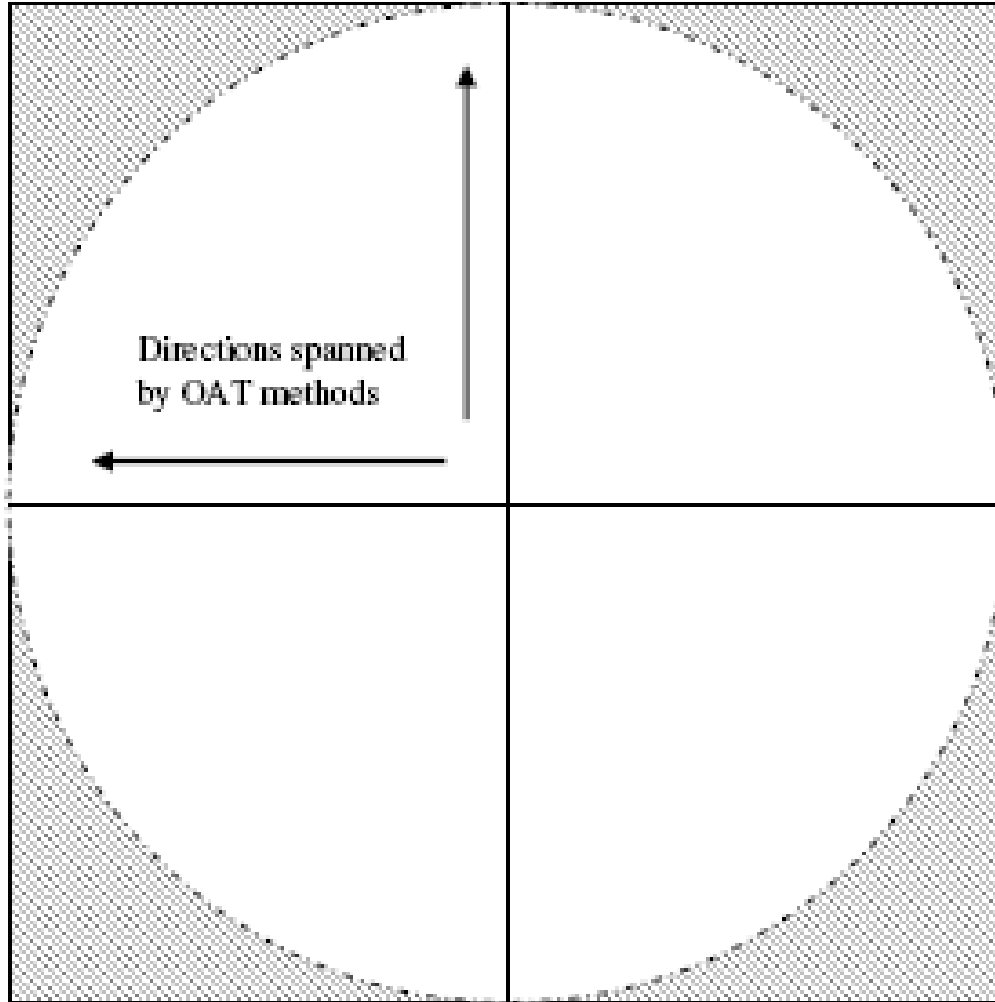
How to avoid a perfunctory sensitivity analysis

Andrea Saltelli*, Paola Annoni

Joint Research Center, Institute for the Protection and Security of the Citizen, via E.Fermi, 2749, Ispra VA 21027, Italy



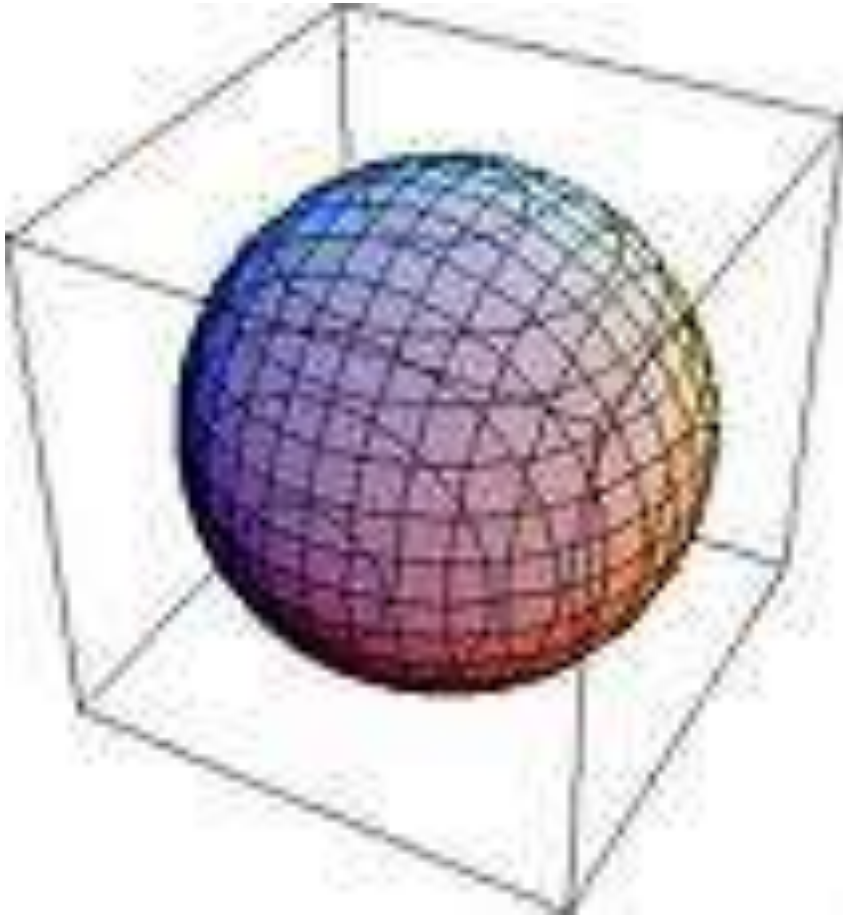
OAT in 2 dimensions



Area circle
/ area
square =?

~ 3/4

OAT in 3 dimensions



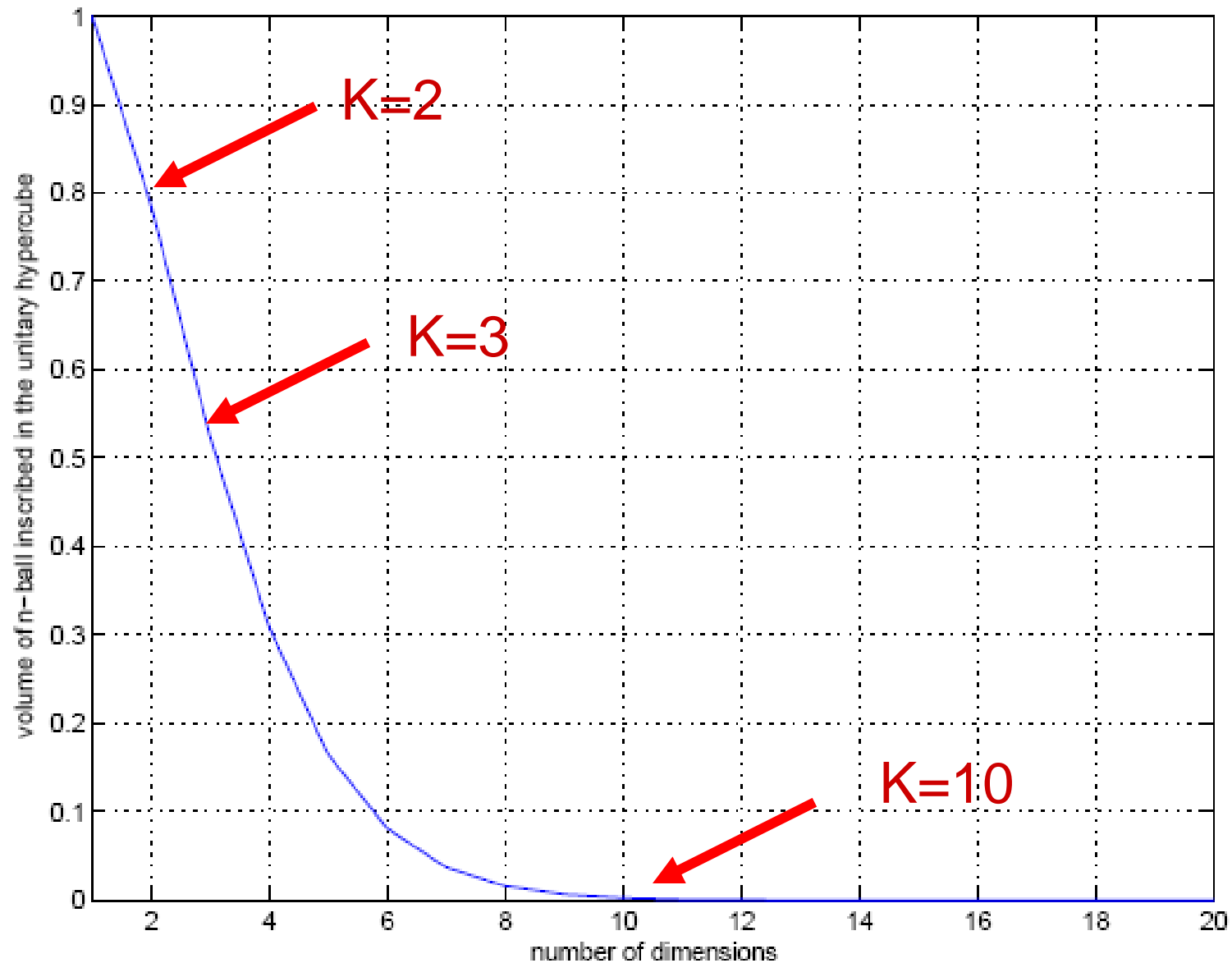
Volume sphere /
volume cube =?

~ 1/2

OAT in 10 dimensions; Volume
hypersphere / volume ten dimensional
hypercube =? ~ 0.0025



OAT in k dimensions

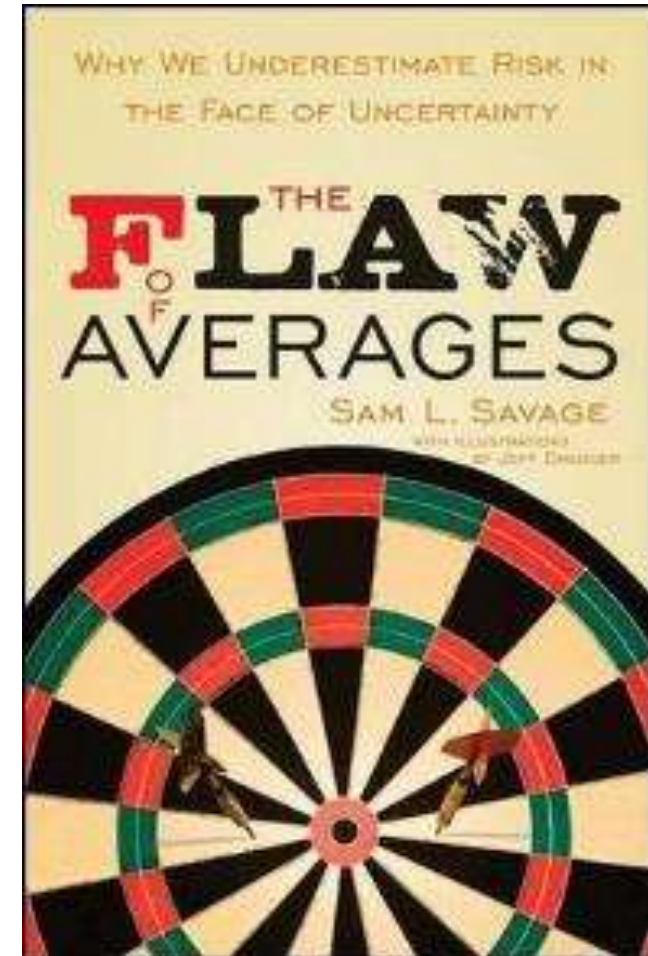
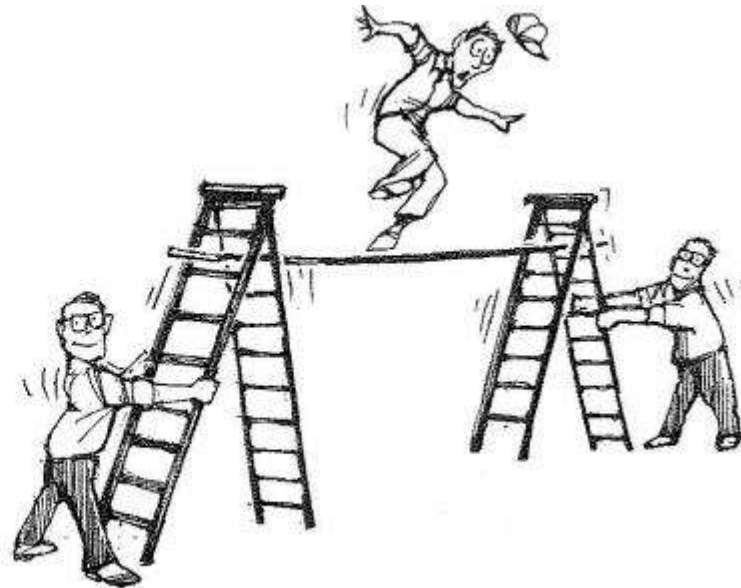


How would you test the scaffolding?

How coupled ladders are shaken in most of available literature



How to shake coupled ladders

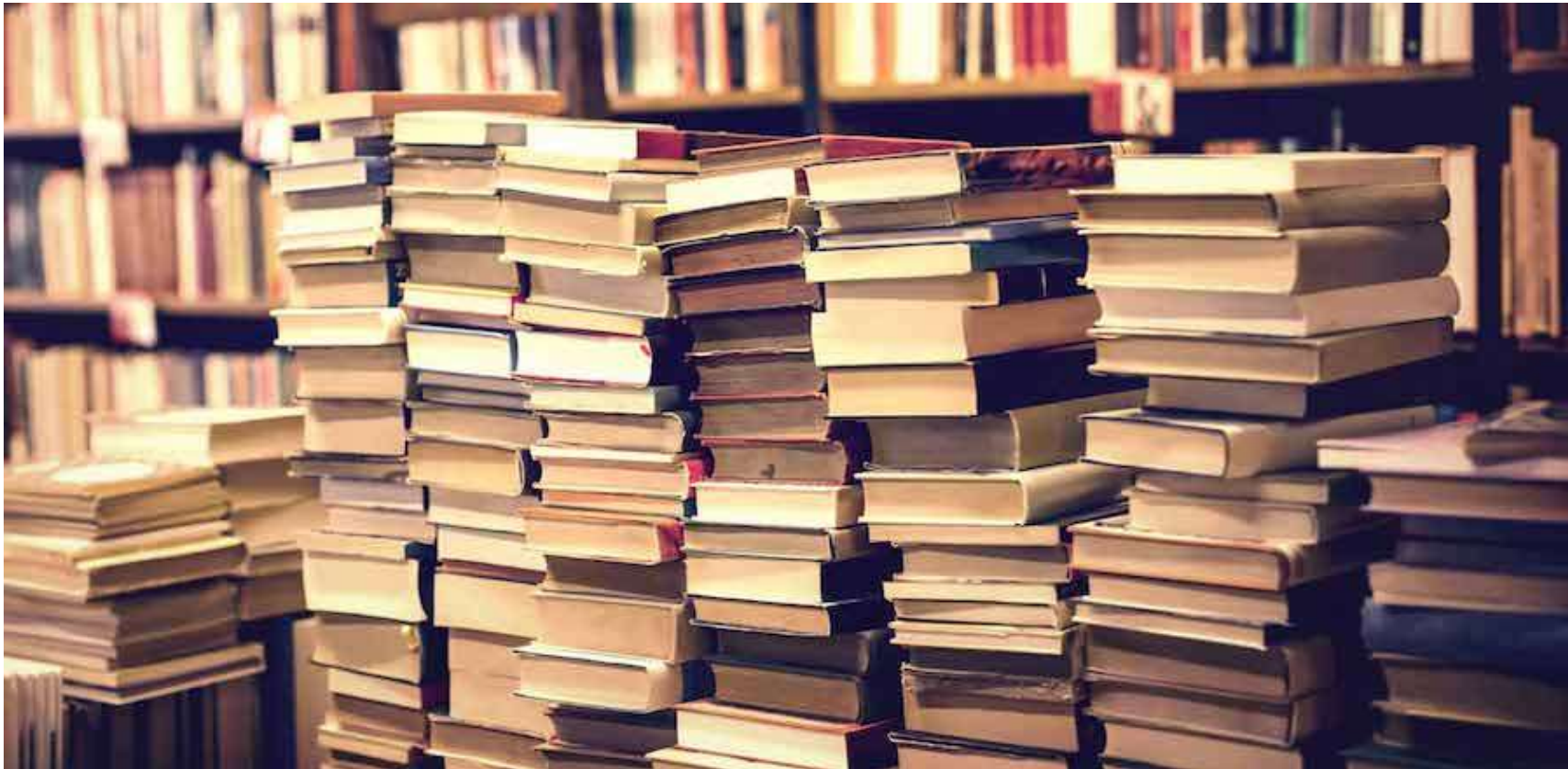


The End

@andreasaltelli



Extra slides







Environmental Modelling & Software

Volume 114, April 2019, Pages 29-39



Why so many published sensitivity analyses are false: A systematic review of sensitivity analysis practices

Andrea Saltelli ^{a, b}  , Ksenia Aleksankina ^c, William Becker ^d, Pamela Fennell ^e, Federico Ferretti ^d, Niels Holst ^f, Sushan Li ^g, Qiongli Wu ^h

Literature search in Scopus

Query: “sensitivity analysis” & “model/modelling”
& “uncertainty”; years 2012–2017; journal
articles; in English

➔ 6000 articles

- AgrBioSci (Agricultural and Biological Sciences)
- BiochemGenMBio (Biochemistry, Genetics and Molecular Biology)
- BusManAcc (Business, Management and Accounting)
- Chemi (Chemistry)
- ChemEng (Chemical Engineering)
- CompSci (Computer Science)
- DecSci (Decisional Science)
- EarthSci (Earth and Planetary Sciences)
- EconFin (Economy and Finance)
- Energy (Energy)
- Engineering (Engineering)
- EnvSci (Environmental Science)
- ImmunMicrobio (Immunology and Microbiology)
- MatSci (Material Science)
- Math (Math)
- Medicine (Medicine)
- PharTox (Pharmacology and Toxicology)
- PhysAstro (Physics and Astronomy)
- SocSci (Social Science)

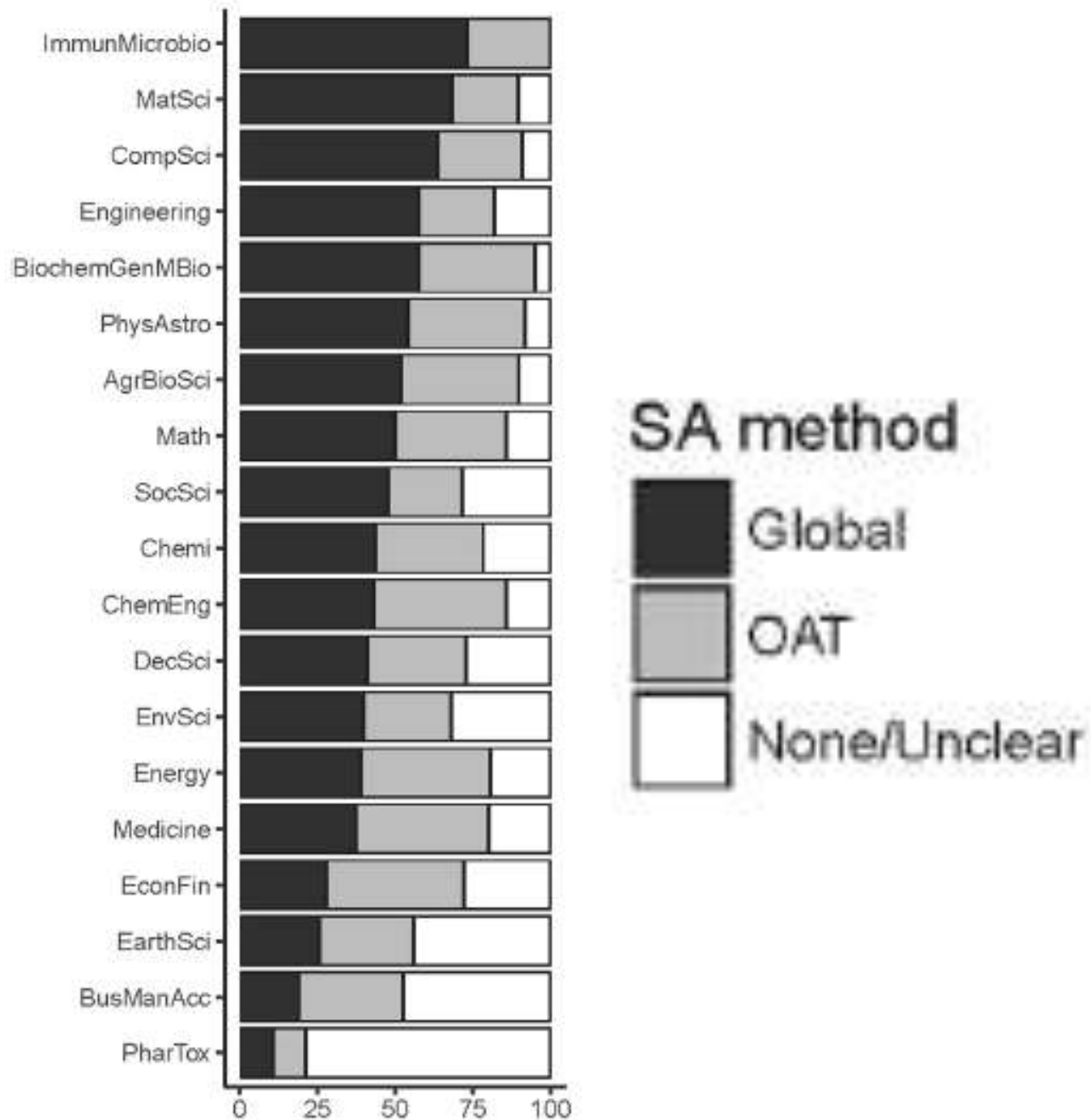
subject areas >100 articles

Taking the top twenty most-cited papers in each subject area:

→ 324 articles, divided among authors

Cleansing manually irrelevant articles:

→ 280 articles



Still many papers
apply an OAT SA:
65%

What if the model is truly linear?

Linear	7%
Nonlinear	61%
Unclear	32%

Linear	7%
Nonlinear	61%
Unclear	32%

65% highly cited articles are OAT

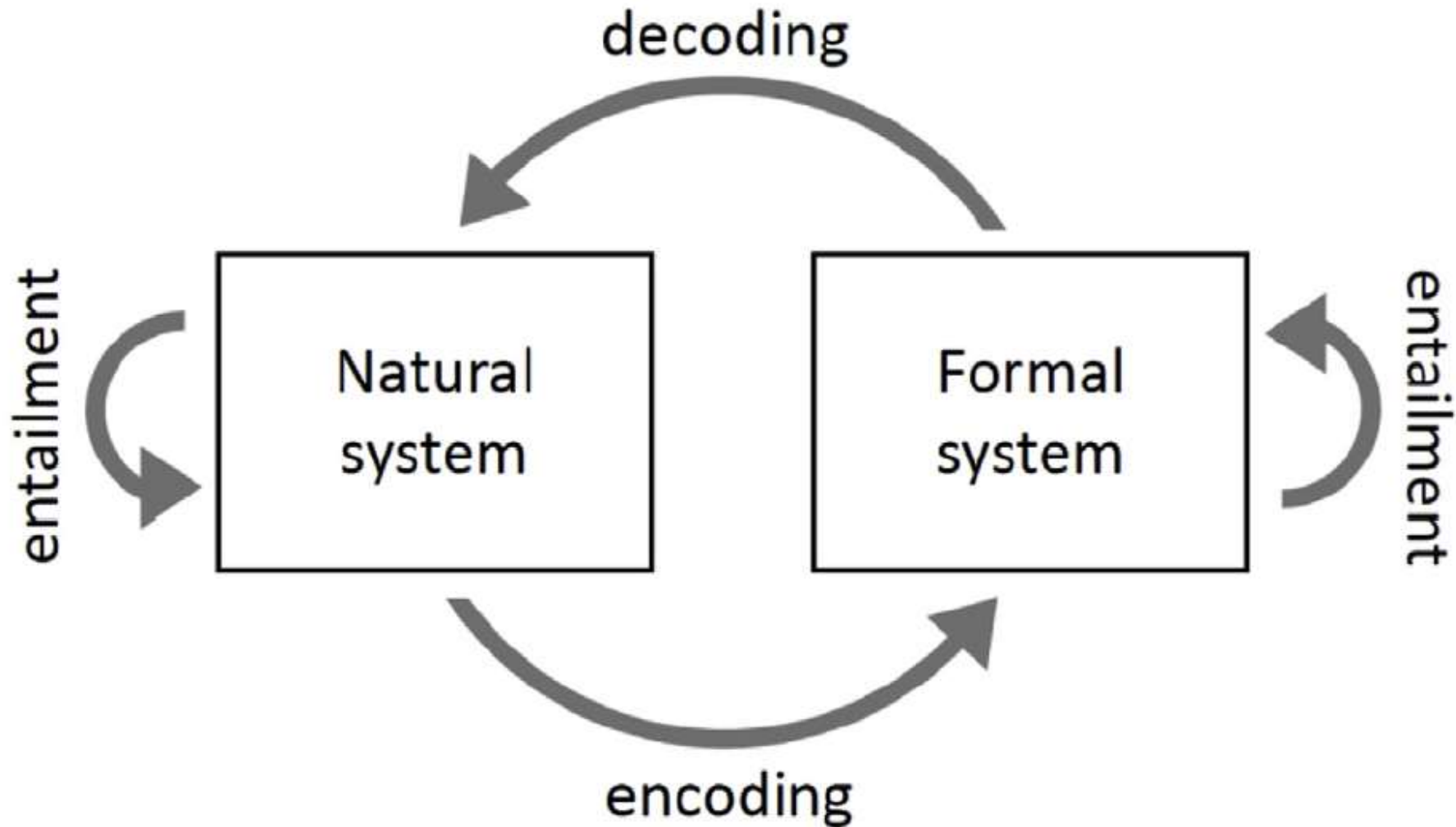
Taking all unclear = linear → still
over 20% of papers wrong
(OAT & non-linear model)

Why?

5. Discussion

5.1. Reasons for bad practice

Why? ➔ 1. Modelling as a craft



Why? ➔ 2. Each discipline going about modelling on its own separate way; pockets of SA practitioners (out of our 280 papers, 35 were methodological, of which 24 suggest global SA)

Why? ➔ 3. Mathematical modelling is not
a discipline

Based on a survey of modellers: “there is no dominating paradigm in modelling and simulation... simulation verification is mostly a trial and error activity ➔ challenges model/simulation validity”

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.

... mathematical modelling cannot do this:



**AMERICAN STATISTICAL ASSOCIATION RELEASES STATEMENT ON
STATISTICAL SIGNIFICANCE AND *P*-VALUES**

*Provides Principles to Improve the Conduct and Interpretation of Quantitative
Science*

March 7, 2016

Wasserstein, R.L. and Lazar, N.A., 2016. 'The ASA's statement on p-values: context, process, and purpose', *The American Statistician*, Volume 70, 2016 – Issue 2, Pages 129–133.

Why? ➡ 4. Good practices require
training in statistics

Why? ➔ 5. More time is needed; though mature global sensitivity analysis methods around for more than 25 years researchers tend to emulate methods found in highly cited papers assuming that they are best practice

Why? ➔ 6. Strategic reasons: global SA is bad if one wants to play the uncertainty game, inflating or deflating uncertainties instrumentally

Solutions? 1. Statistics as a discipline
takes responsibility for statistical
methods for
model validation and verification

Example: who can authoritatively suggest
to modellers not to overinterpret results
from multi-model ensembles?

Climate Models as Economic Guides: Scientific Challenge or Quixotic Quest?

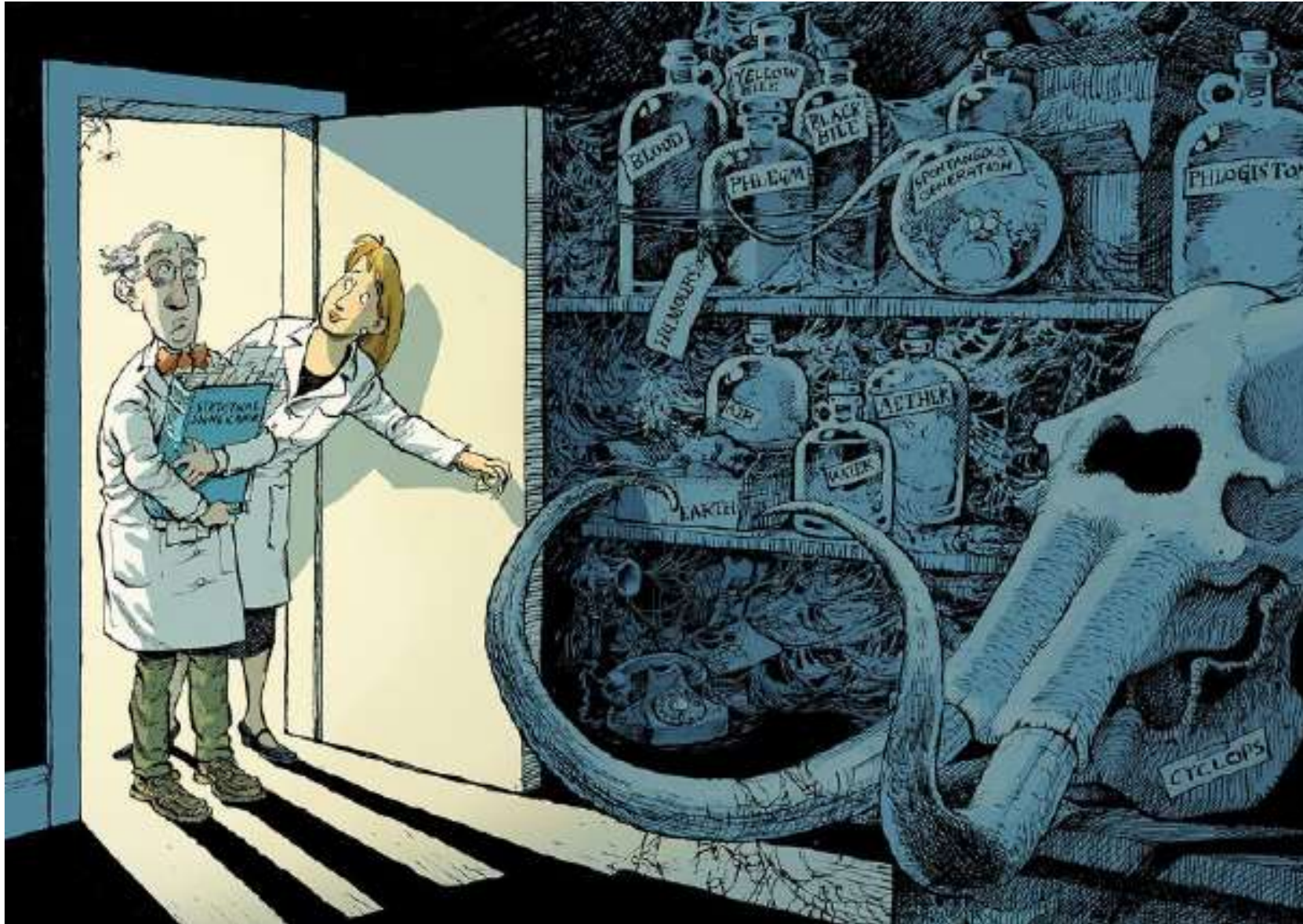
BY ANDREA SALTELLI, PHILIP B. STARK, WILLIAM BECKER, PAWEL STANO

Climate Models as Economic Guides: Scientific Challenge or Quixotic Quest?

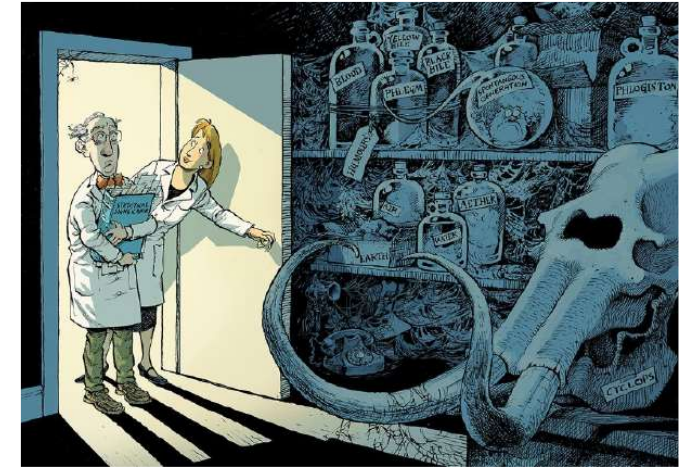
BY ANDREA SALTELLI, PHILIP B. STARK, WILLIAM BECKER, PAWEL STANO

A plea against audacious risk or cost-benefit analysis running over centennial time scales; example: crime rate as modified by climate change at US county level in 2100

Solutions? 2. Learn from what happens in statistics where the p-test crisis is being tackled head on



Throw away
the concept of
statistical
significance?



COMMENT • 20 MARCH 2019

Scientists rise up against statistical significance

Valentin Amrhein, Sander Greenland, Blake McShane and more than 800 signatories call for an end to hyped claims and the dismissal of possibly crucial effects.

Valentin Amrhein , Sander Greenland & Blake McShane

See the discussion on the blog of Andrew Gelman <https://statmodeling.stat.columbia.edu/>

IN PRACTICE



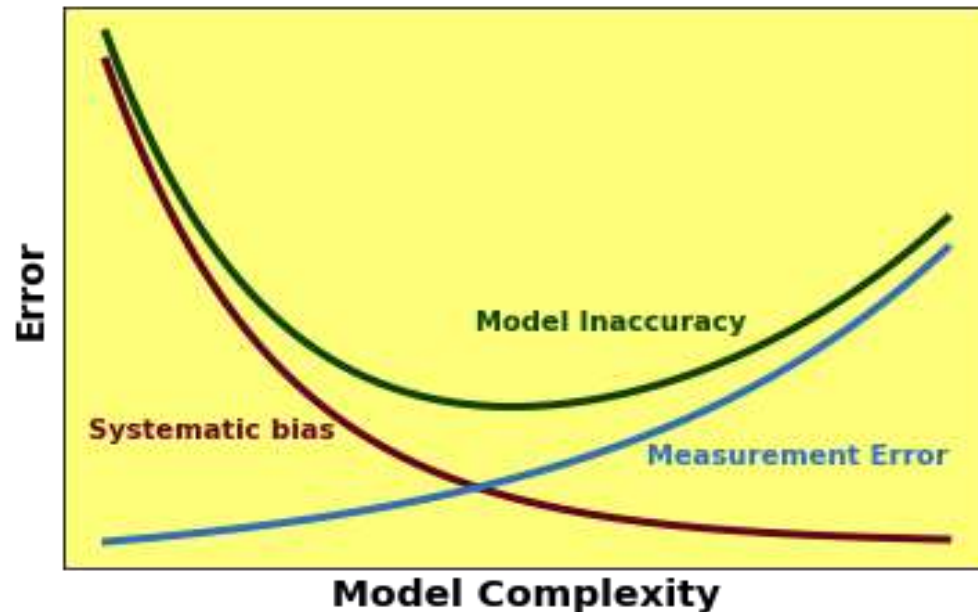
Cargo-cult statistics and scientific crisis

The mechanical, ritualistic application of statistics is contributing to a crisis in science. Education, software and peer review have encouraged poor practice – and it is time for statisticians to fight back. By **Philip B. Stark** and **Andrea Saltelli**

Lessons for sensitivity analysis

- Global SA
- UA and SA coupled
- Purpose- & context-specific
- The map is not the territory

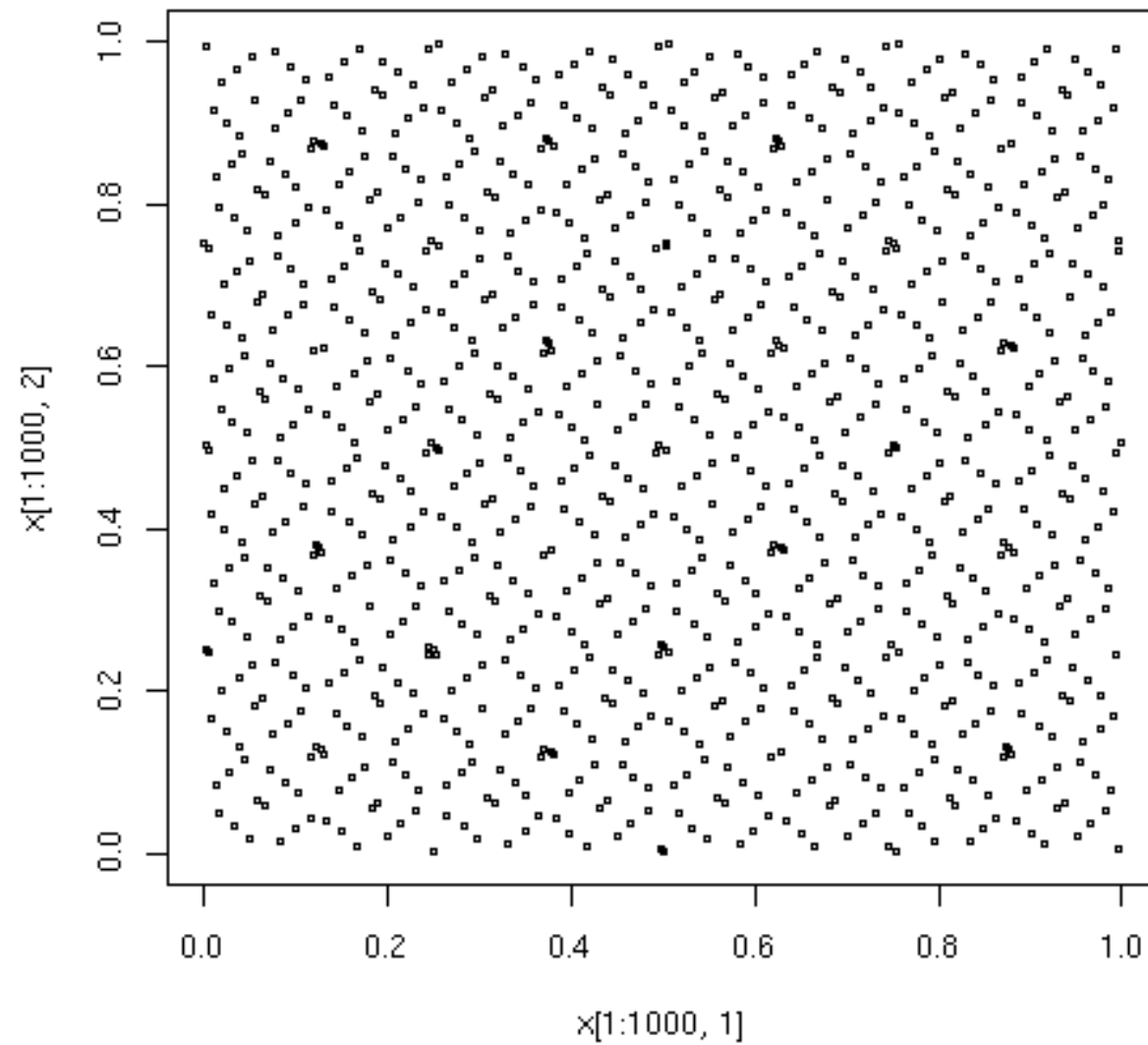
- Memento



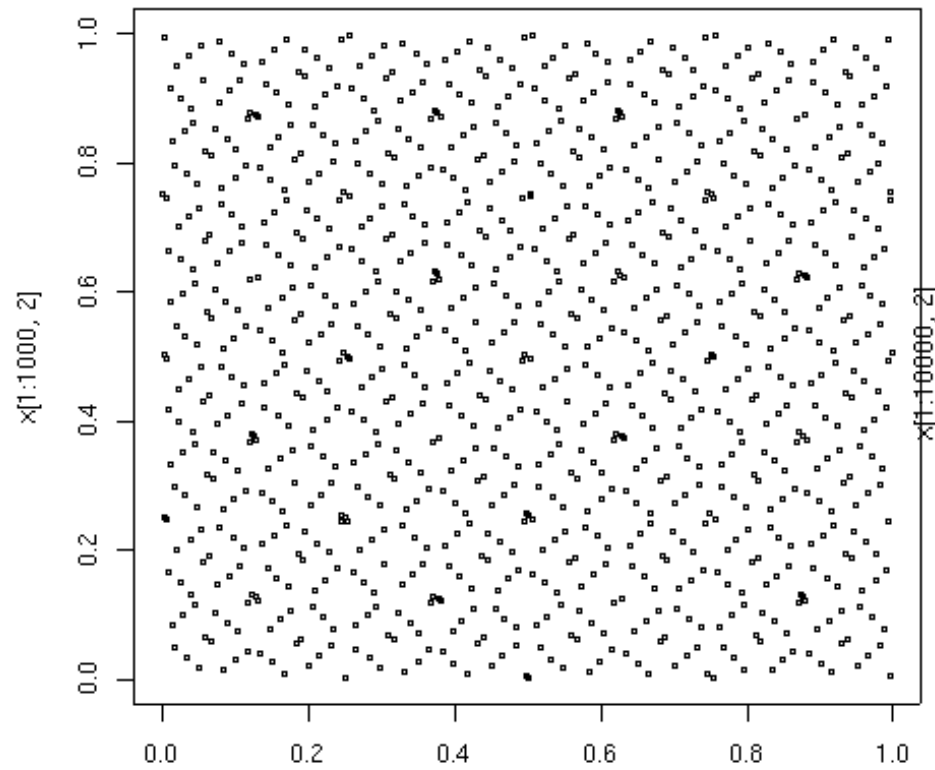


How to generate
the random sample?

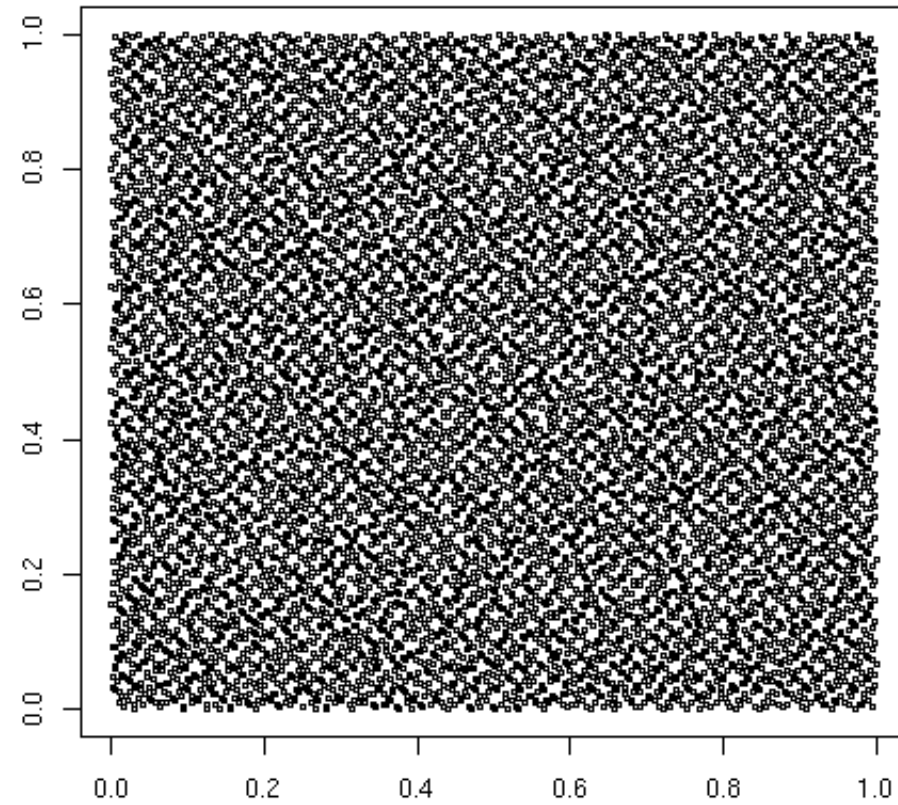
Quasi random
sequences
developed by I.M.
Sobol'



An LP_τ sequence

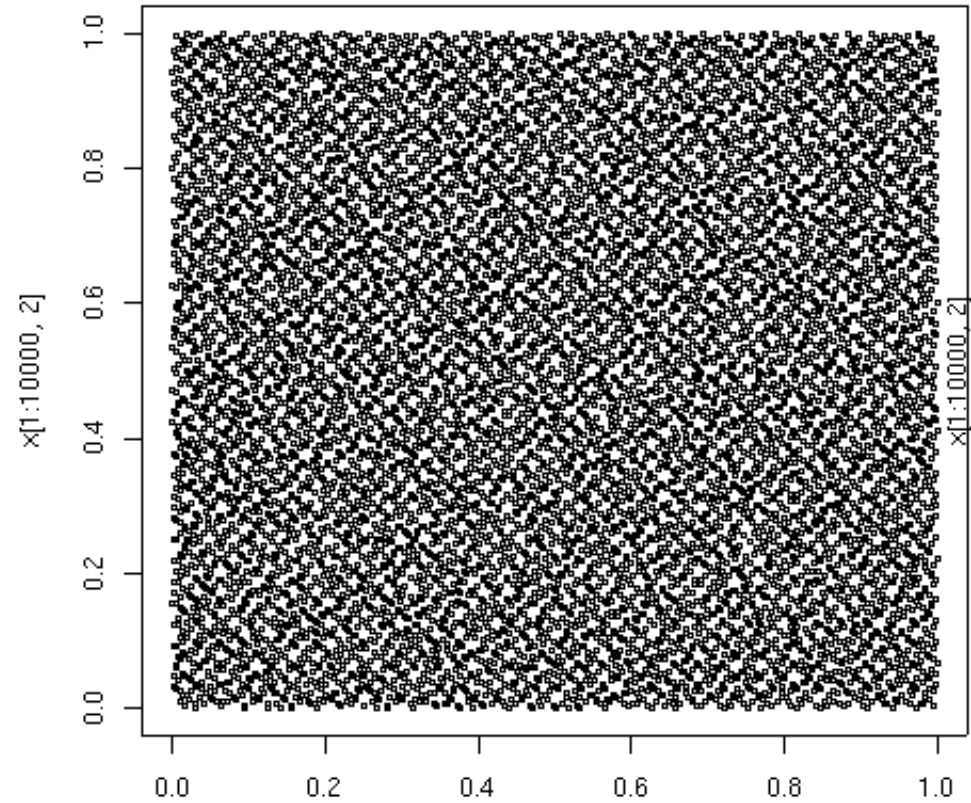


X_1, X_2 plane, 1000 Sobol' points

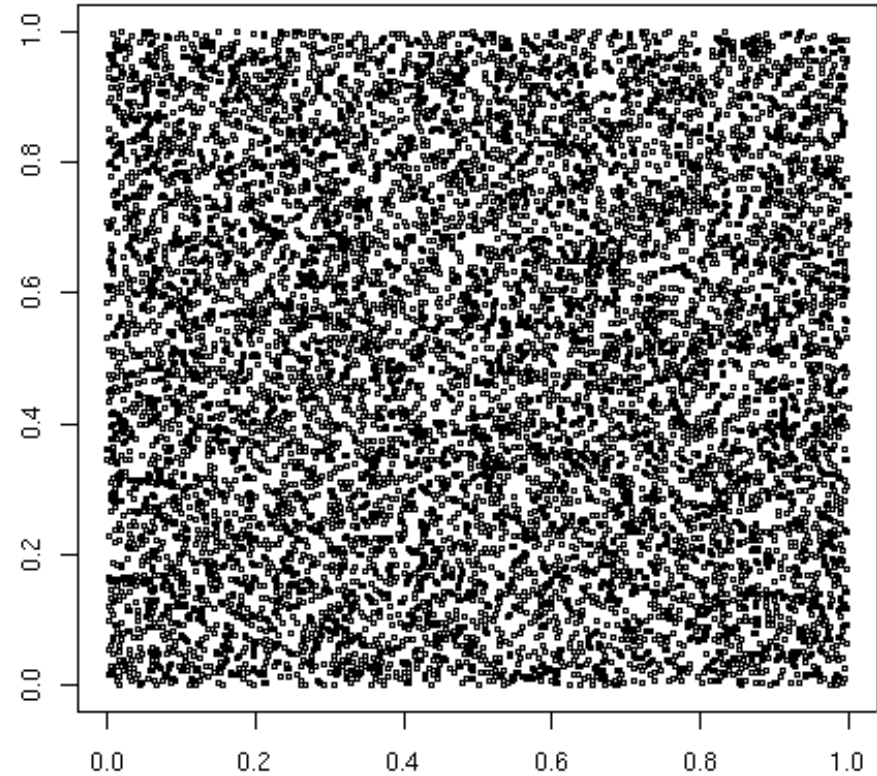


X_1, X_2 plane, 10000 Sobol' points

Sobol' sequences of quasi-random points



X_1, X_2 plane, 10000 Sobol' points



X_1, X_2 plane, 10000 random points

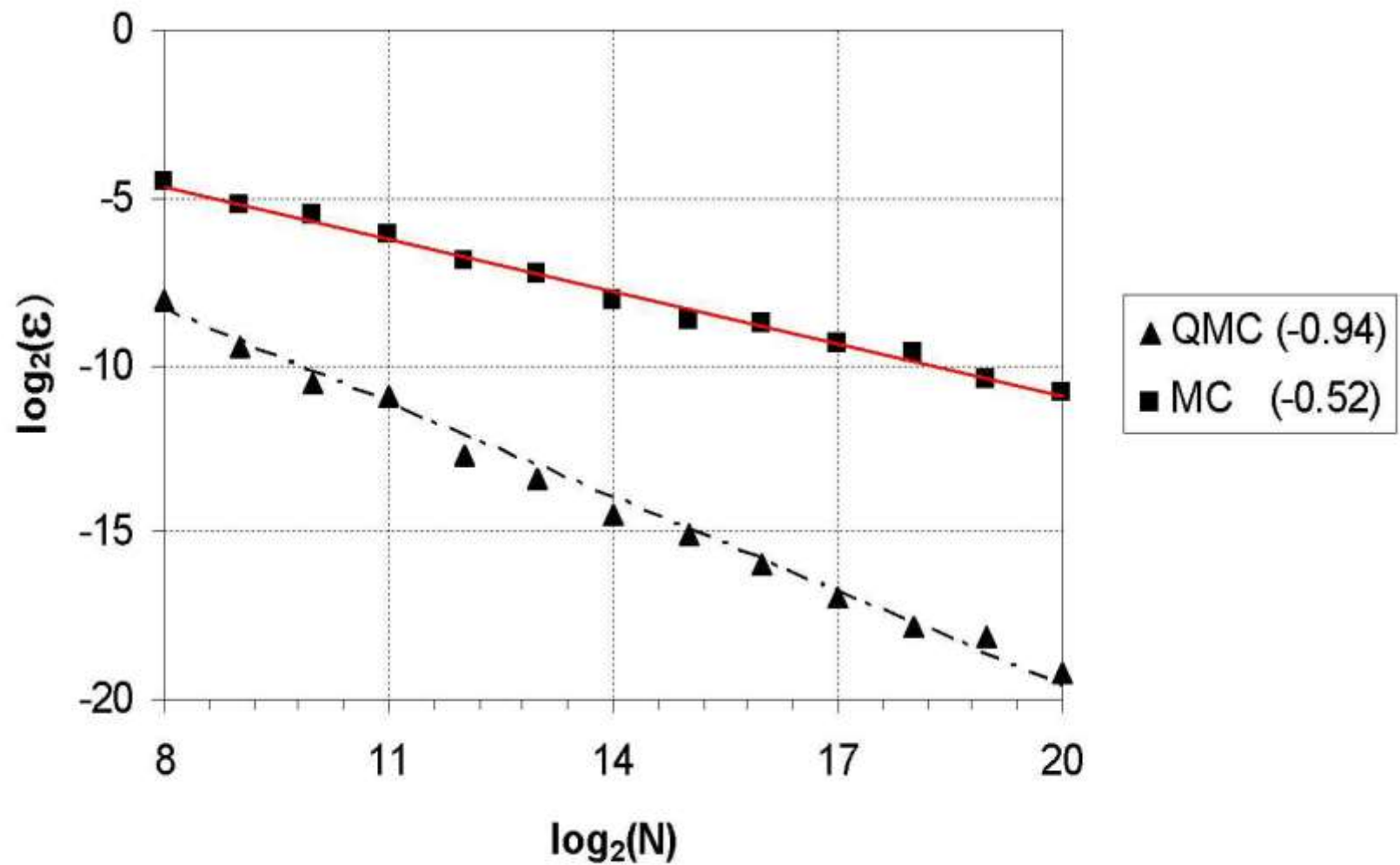
Sobol' sequences of quasi-random points
against random points

Why quasi-random: they have faster convergence



Sergei Kucherenko,
Imperial College London

Kucherenko S., Feil B., Shah N., Mauntz W. The identification of model effective dimensions using global sensitivity analysis Reliability Engineering and System Safety 96 (2011) 440–449.



$$\varepsilon = \left(\frac{1}{K} \sum_{k=1}^K (I[f] - I_k[f])^2 \right)^{1/2}$$

$$\sum_{i=1}^n (-1)^i \prod_{j=1}^i x_j$$

Error=numeric-
versus-analytic
value the integral
of the function (for
n=360) over its
dominion.

Root mean square error over K=50 different trials.

The End

@andreasaltelli

