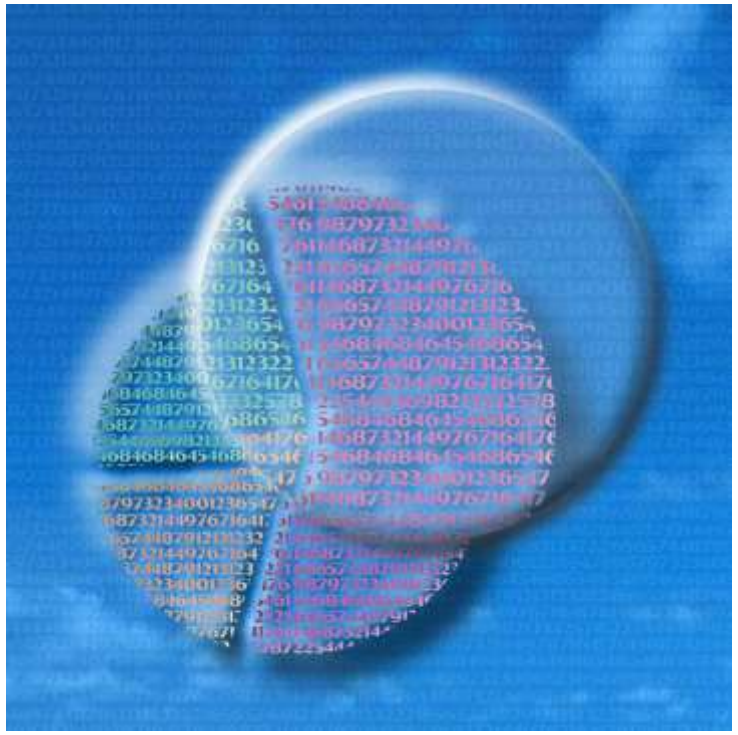


Sensitivity analysis for impact assessment

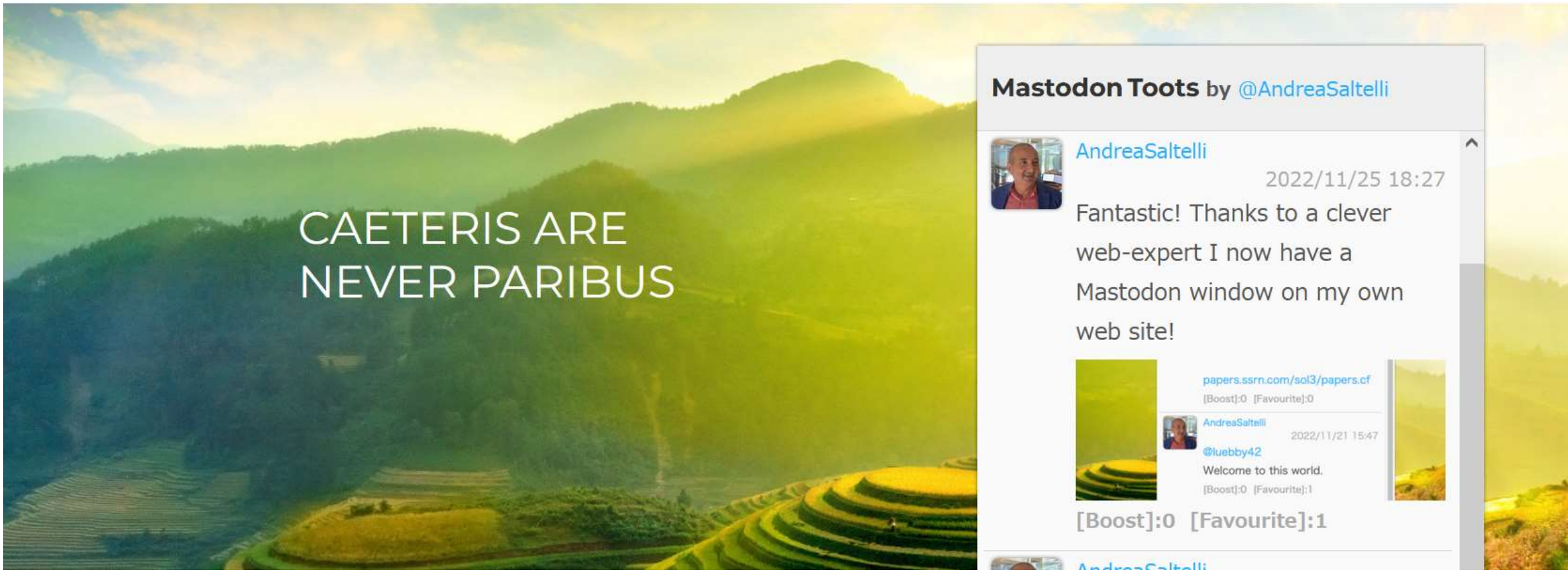
Andrea Saltelli,
November 28 2022

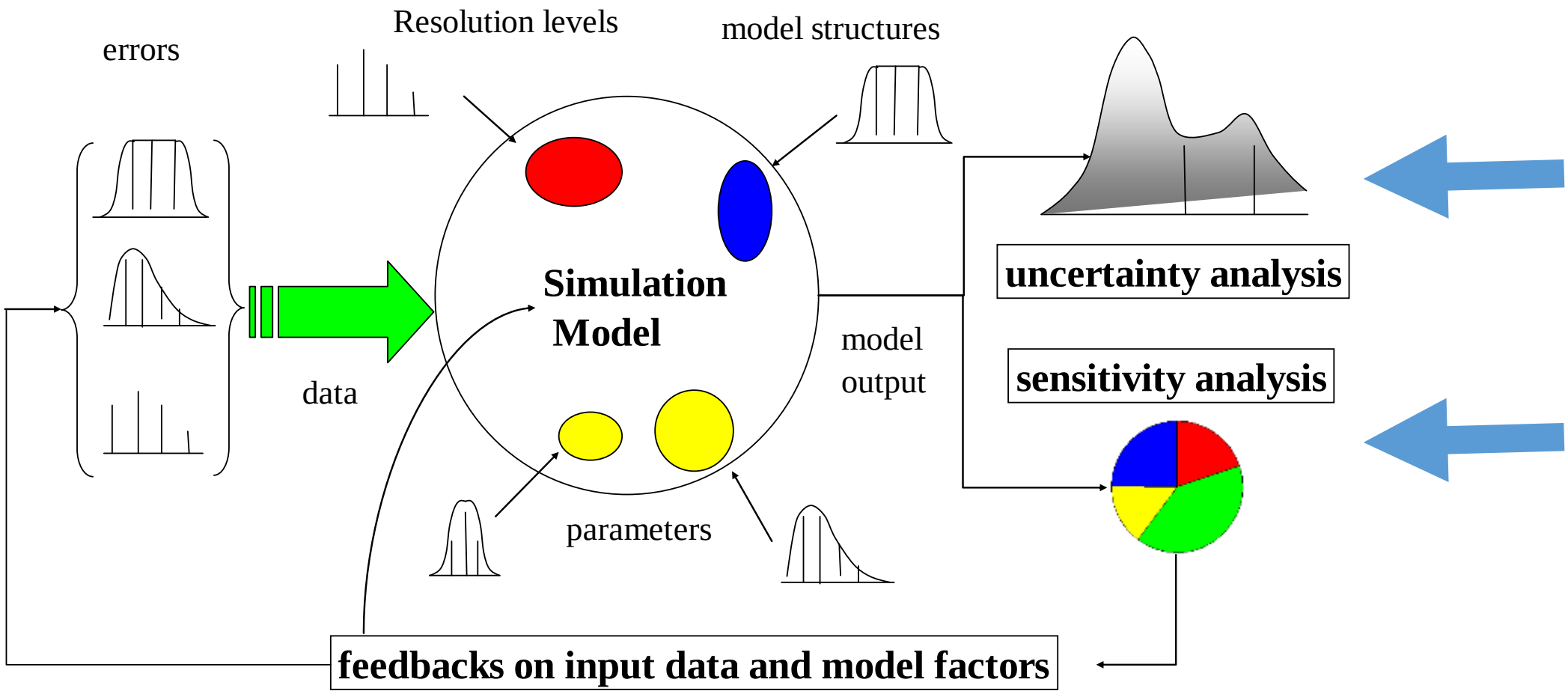
JRC course on sensitivity analysis,
Brussels, November 28-29

First part – 28 Nov
9:30- 10.00 Round table with participants
10:00 -10:30 Welcome, introduction, the use of evidence in the Better Regulation context, models, models in impact assessment (Paul)
10:30 – 11:10 Models, uncertainty and model quality assurance (**Andrea, 40m**)
11:10-11:45 Uncertainty analysis & Sensitivity analysis concept and brief history, Basics of statistics, Monte Carlo method (Stefano)
11.45-12 (break 15 mins)
12:00-12:30 Uncertainty and sensitivity analysis in impact assessment (**Andrea 30m**: stress on OAT vs GSA)
12:30-13:15 Steps of a sensitivity analysis I part (Rossana: OAT example/scatterplot/introduction to SI)
Closure All
Second part – 29 Nov am
9:15-9:45 Steps of a sensitivity analysis II part: variance-based and Sobol' method (Stefano)
9:45-10:20 Use of Siml@b tool for global sensitivity analysis (Rossana)
10:20-10:50 Examples of sensitivity analysis results (**Andrea 30m**)
10:50-11.05 (break 15 mins)
11.05 11.30 Examples of sensitivity analysis results (Stefano)
11:30 -12:30 Sensitivity Auditing (**Andrea 60m**)
Conclusions (with Paul) 12:30 – 12:45

www.andreasaltelli.eu

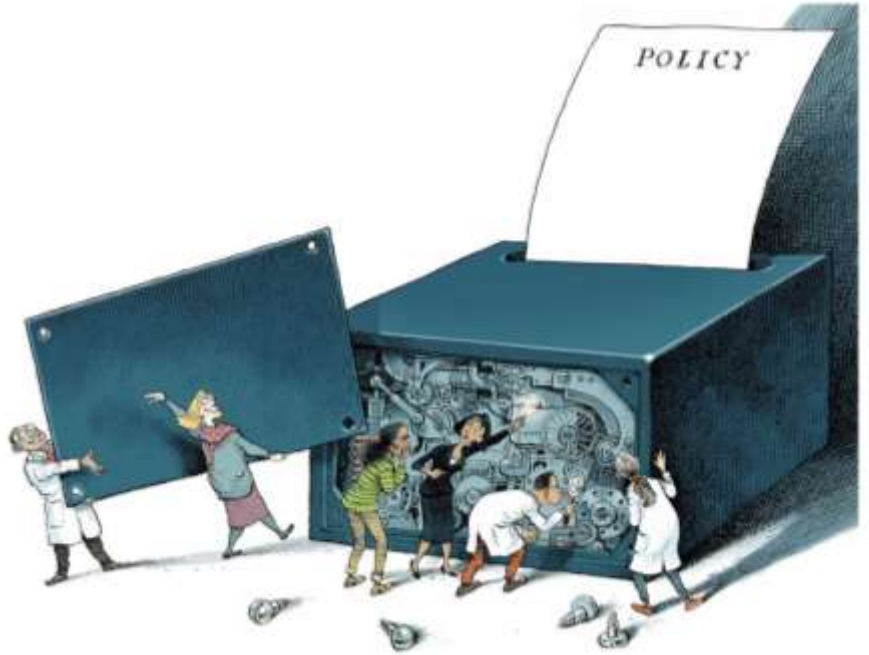
Where to find this talk:



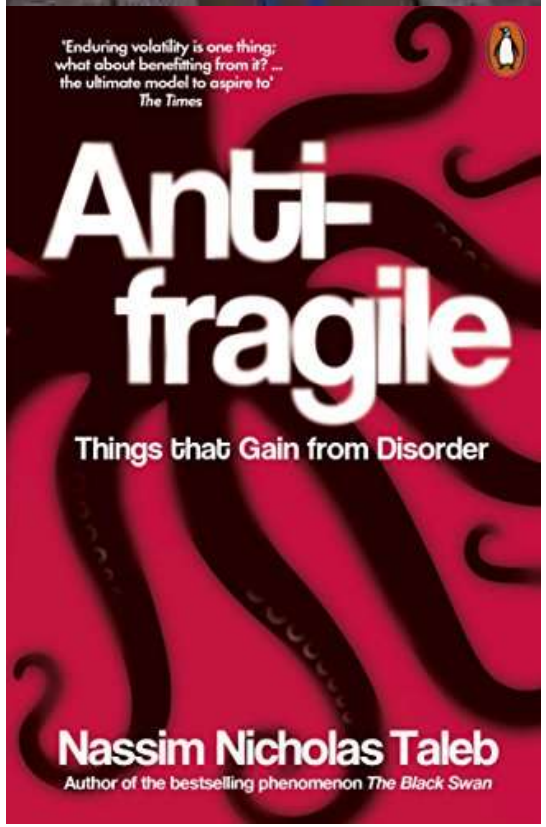

errors
Resolution levels
model structures
Simulation Model
data
model output
parameters
uncertainty analysis
sensitivity analysis
feedbacks on input data and model factors

Mind the assumptions

Assess uncertainty and sensitivity



"Anyone turning to a model for insight should demand that such analyses be conducted, and their results be described adequately and made accessible"



A short trip through sensitivity analysis borrowing N. N. Taleb's *via negativa*

ELSEVIER

Environmental Modelling & Software

Volume 114, April 2019, Pages 29-39

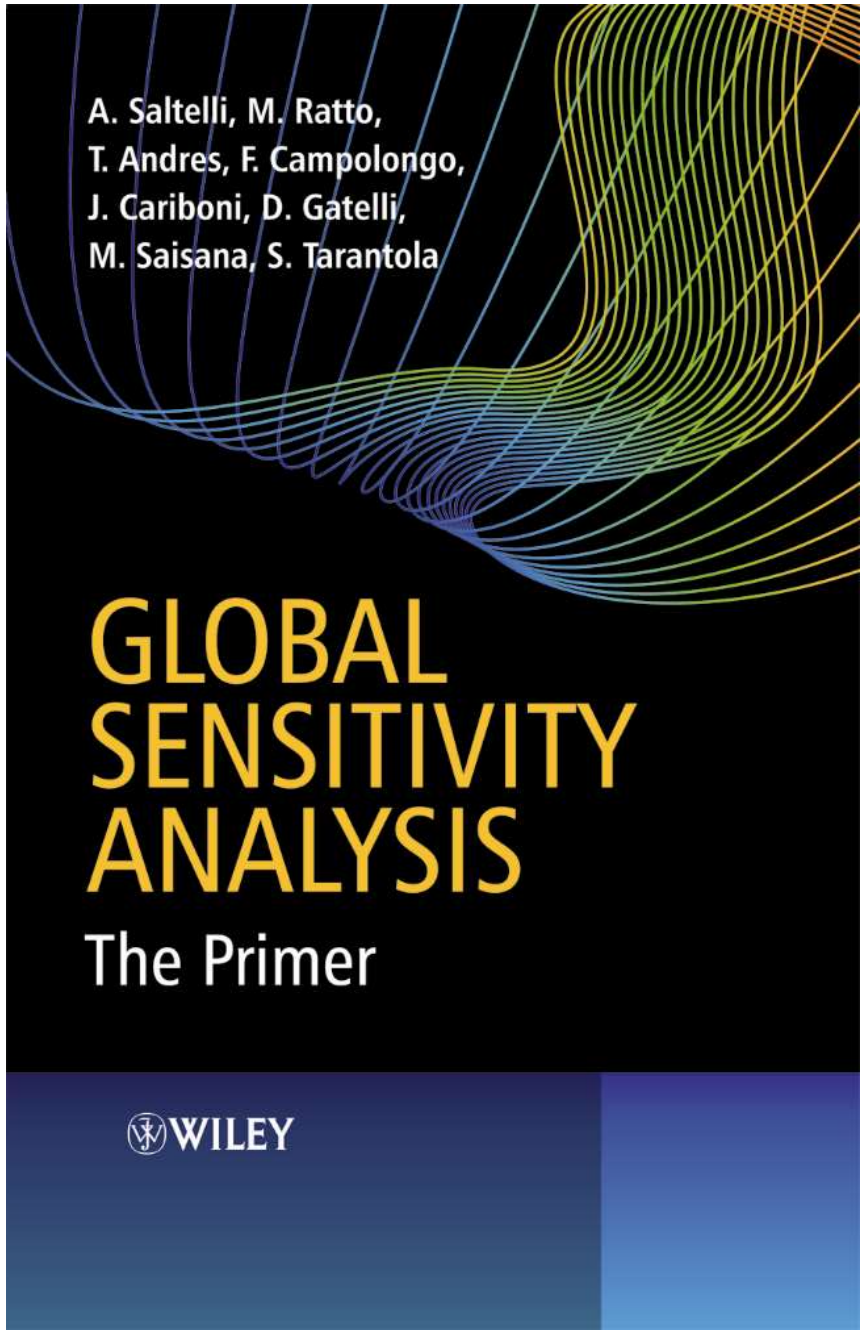
Why so many published sensitivity analyses are false: A systematic review of sensitivity analysis practices

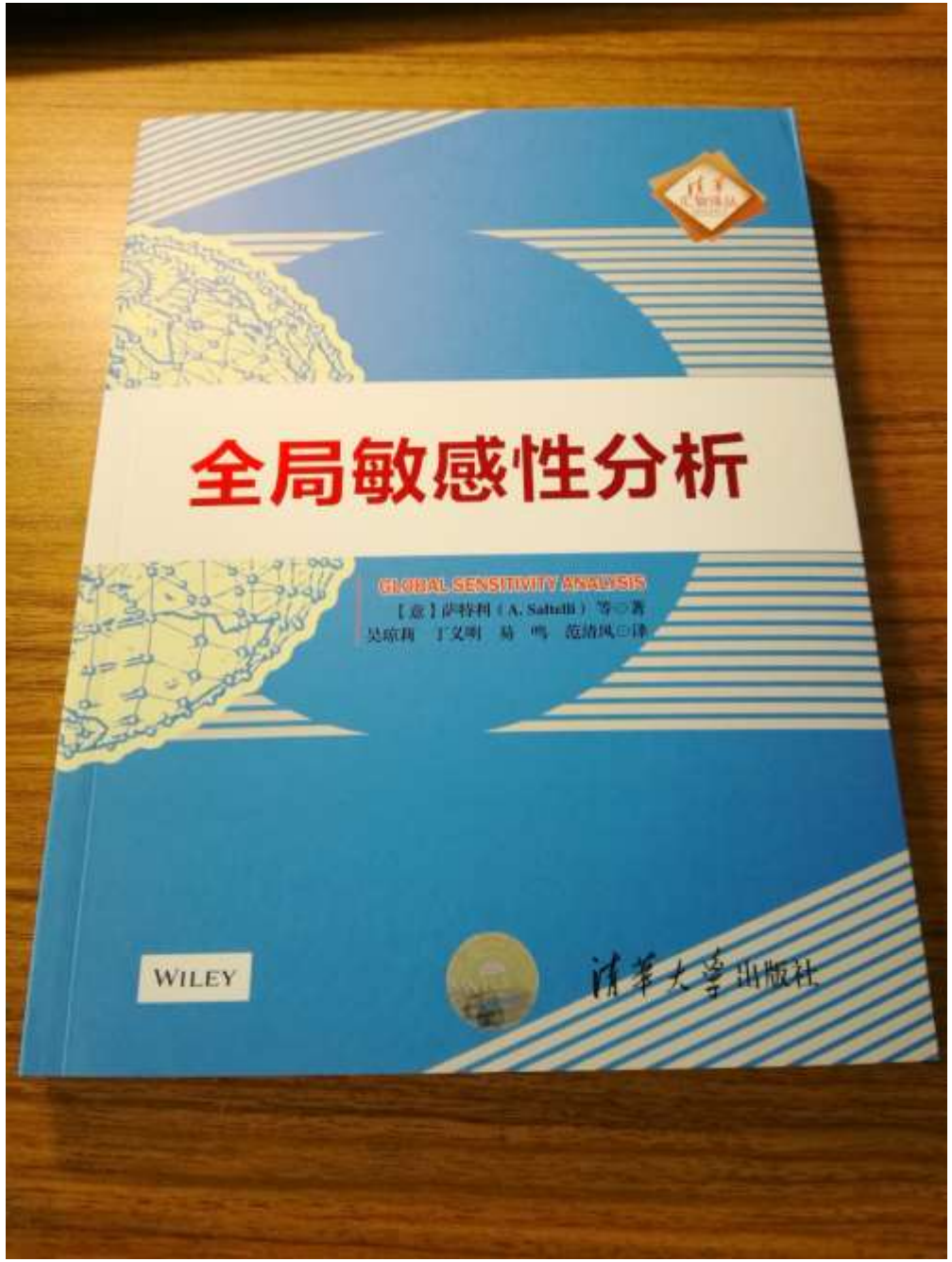
Andrea Saltelli [a, b], Ksenia Aleksankina [c], William Becker [d], Pamela Fennell [e], Federico Ferretti [d], Niels Holst [f], Sushan Li [g], Qiongli Wu [h]

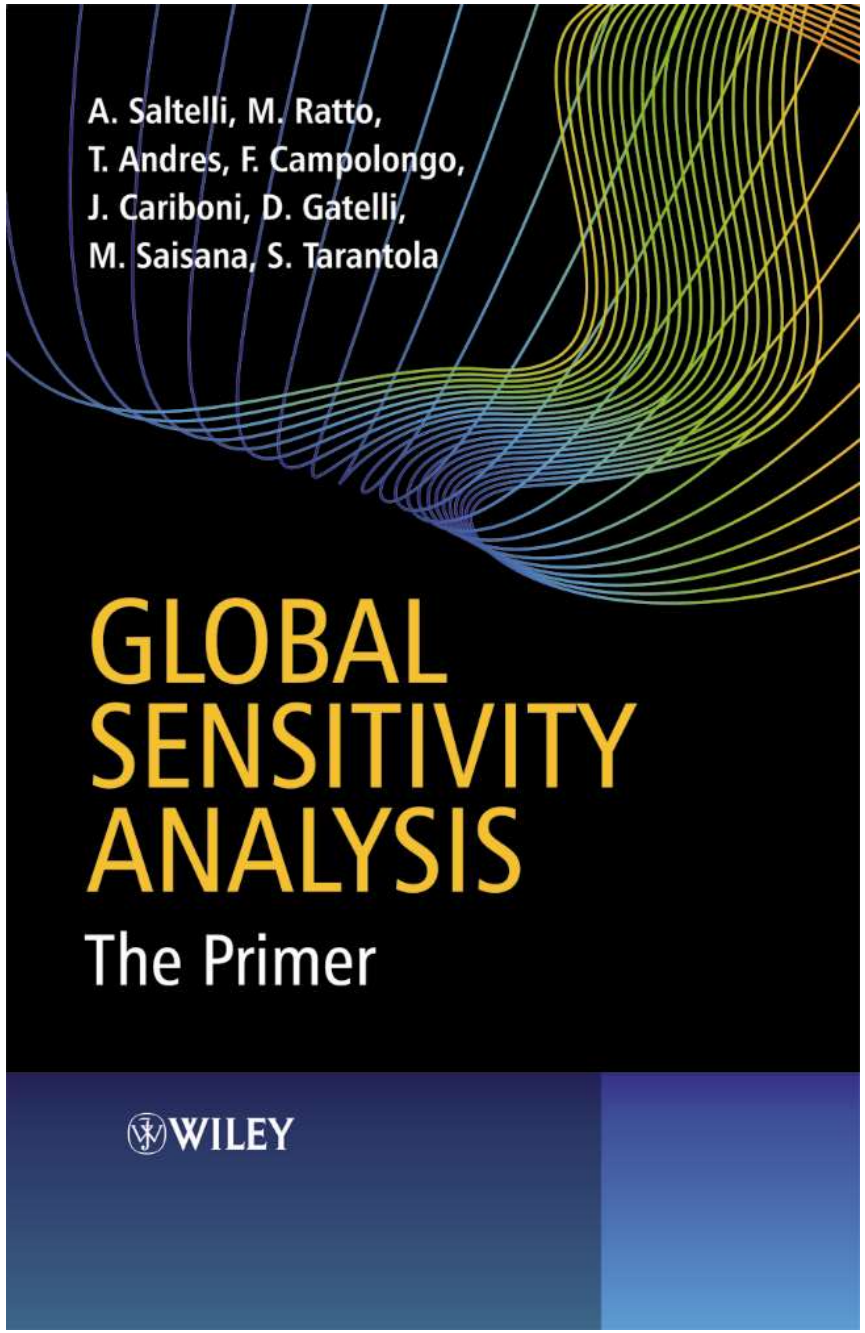
Don’t use just any method

Use the method appropriate to context and purpose

An introduction to variance based methods

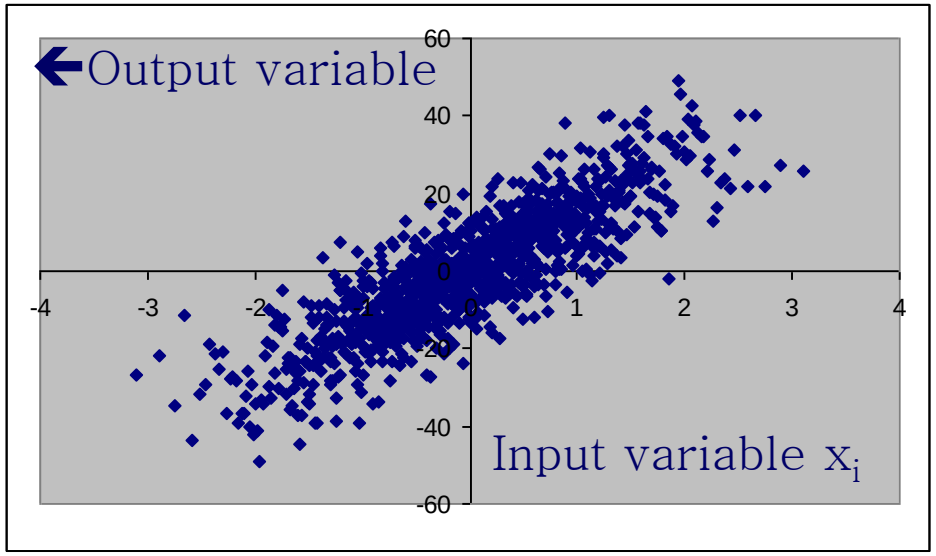

A. Saltelli, M. Ratto,
T. Andres, F. Campolongo,
J. Cariboni, D. Gatelli,
M. Saisana, S. Tarantola
GLOBAL
SENSITIVITY
ANALYSIS
The Primer
WILEY

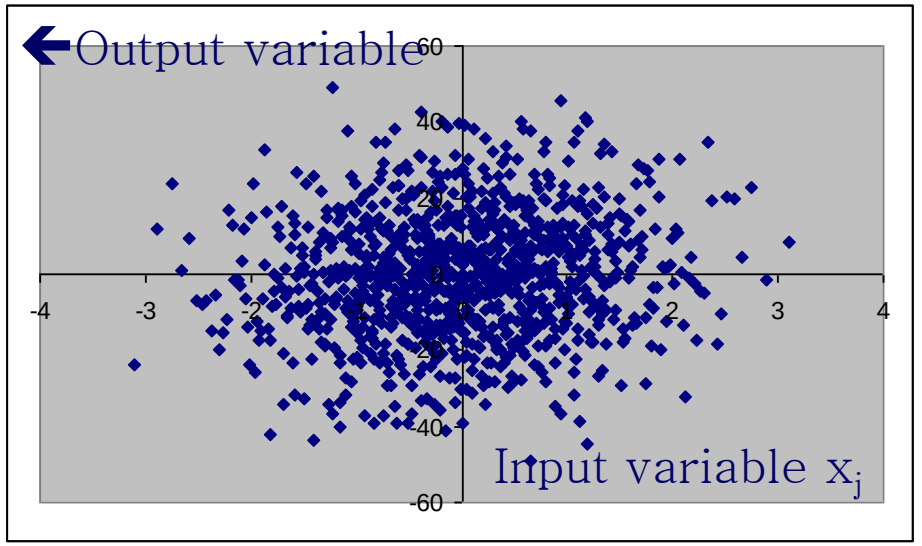

全局敏感性分析
GLOBAL SENSITIVITY ANALYSIS
WILEY



Available for free at

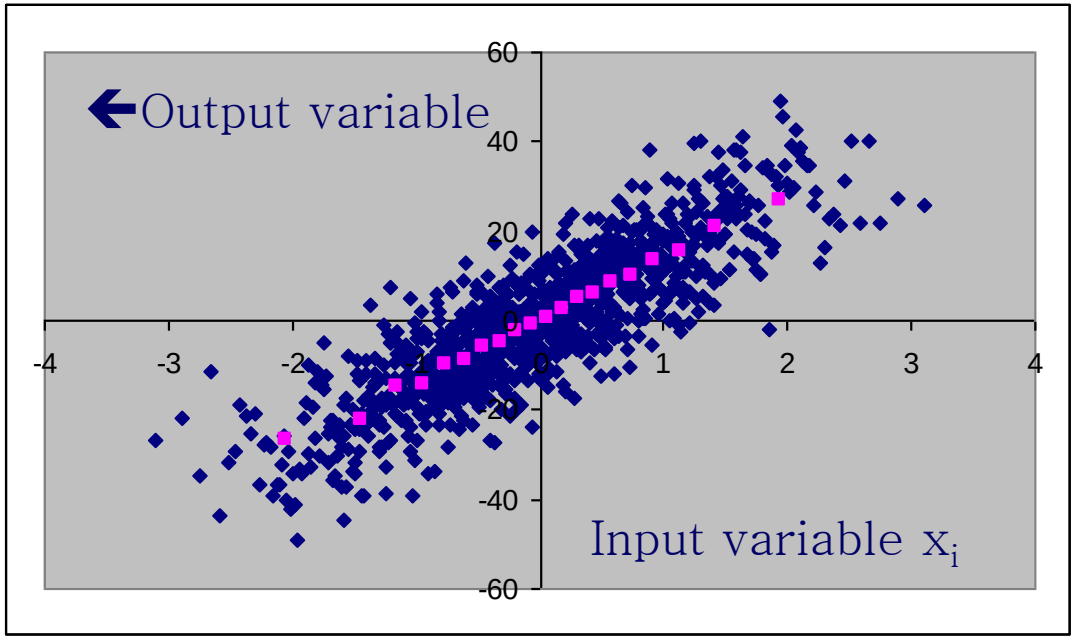
http://www.andreasaltelli.eu

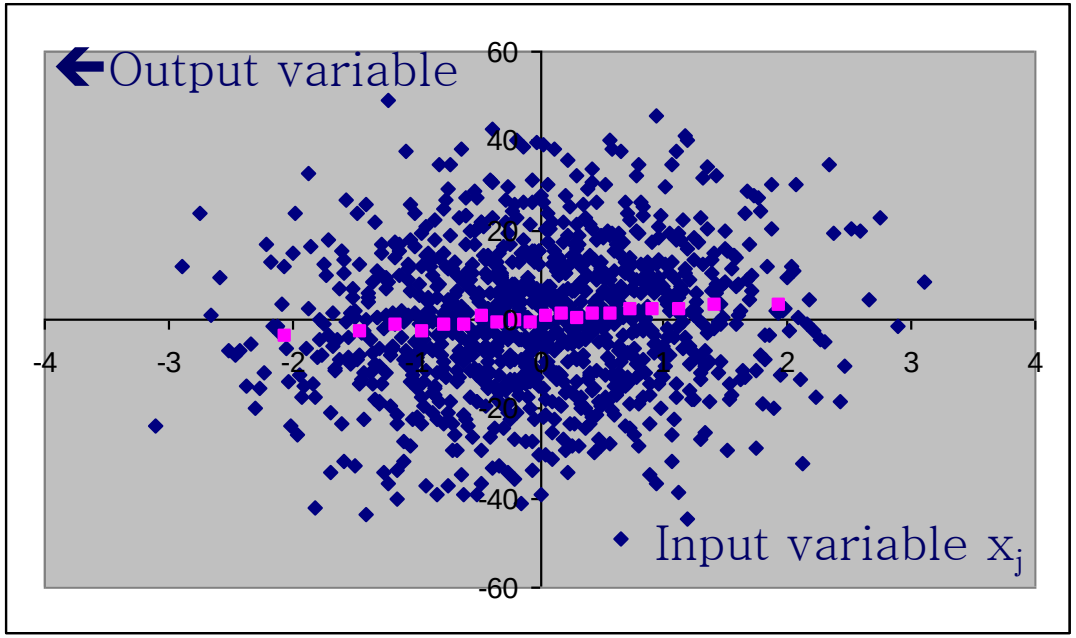




Plotting the output as a function of two different input factors

Which factor is more important?

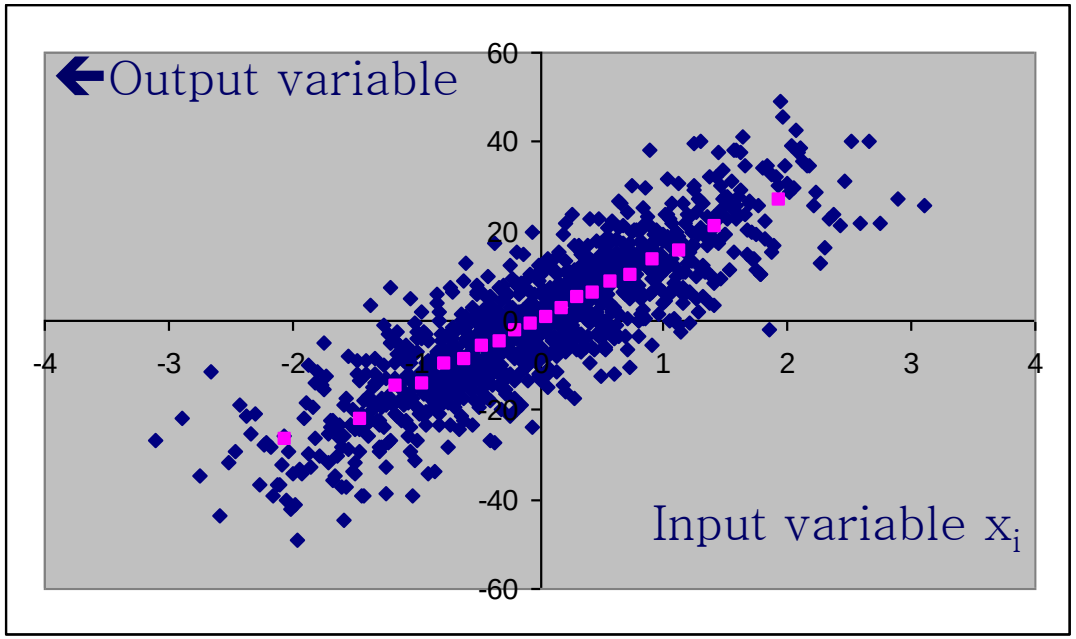




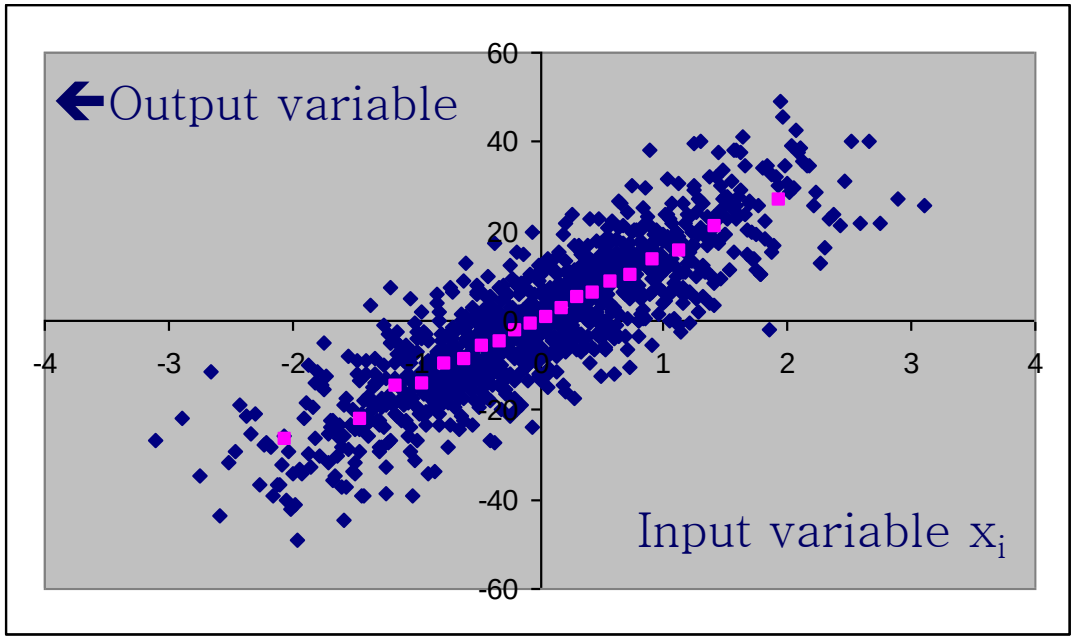
~1,000 blue points

Divide them in 20 bins of ~ 50 points

Compute the bin's average (pink dots)

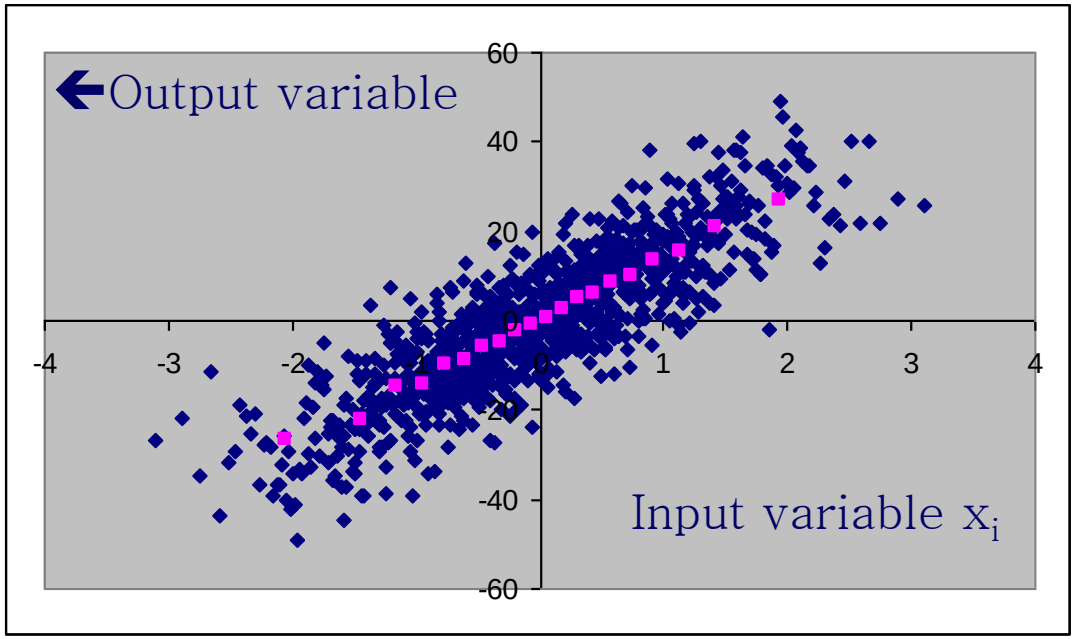


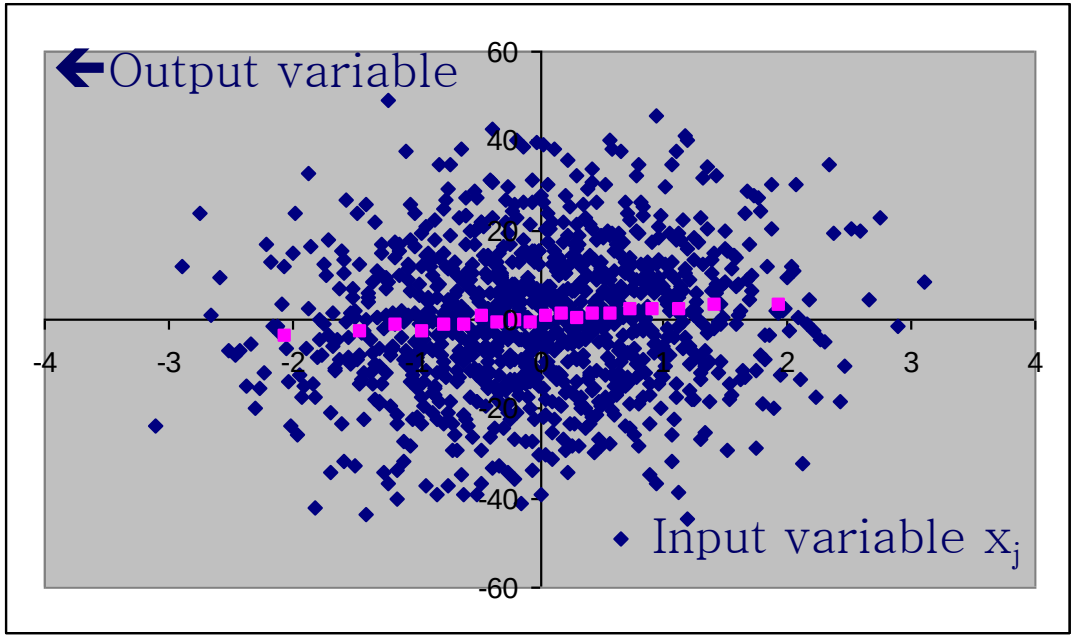
Each pink point is ~ $E_{\mathbf{X}_{\sim i}}\left(Y|X_i\right)$



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

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





Which factor has the highest

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

More on scatterplots and variance based next

The measures and their ‘settings’ = when to use them

Journal of the American Statistical Association ›
Volume 97, 2002 - Issue 459

Enter keywords, authors, DOI, C

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979
Views
286
CrossRef citations to date
6
Altmetric

Primary Article

On the Relative Importance of Input Factors in Mathematical Models

Safety Assessment for Nuclear Waste Disposal

Andrea Saltelli & Stefano Tarantola

Pages 702-709 | Published online: 31 Dec 2011

Download citation https://doi.org/10.1198/016214502388618447

The measures and their ‘settings’ = when to use them

First order effect	Factor prioritization (orienting research)
Total effect	Factor fixing (model simplification)

ELSEVIER

Computer Physics Communications

Volume 145, Issue 2, 15 May 2002, Pages 280-297

Making best use of model evaluations to compute sensitivity indices

Andrea Saltelli ✉ ⊕

Computing the indices efficiently

Higher order Sobol' indices

Get access >

Art B. Owen ✉, Josef Dick, Su Chen

Information and Inference: A Journal of the IMA, Volume 3, Issue 1, March 2014, Pages 59–81, https://doi.org/10.1093/imaiai/iau001

Published: 01 March 2014 **Article history** ▾

Plenty of code available in R, MATLAB, and Phyton

https://cran.r-project.org/web/packages/sensitivity/sensitivity.pdf

https://cran.rstudio.com/web/packages/sensobol/index.html

https://www.uqlab.com/ (in MatLab, by Bruno Sudret and his team)

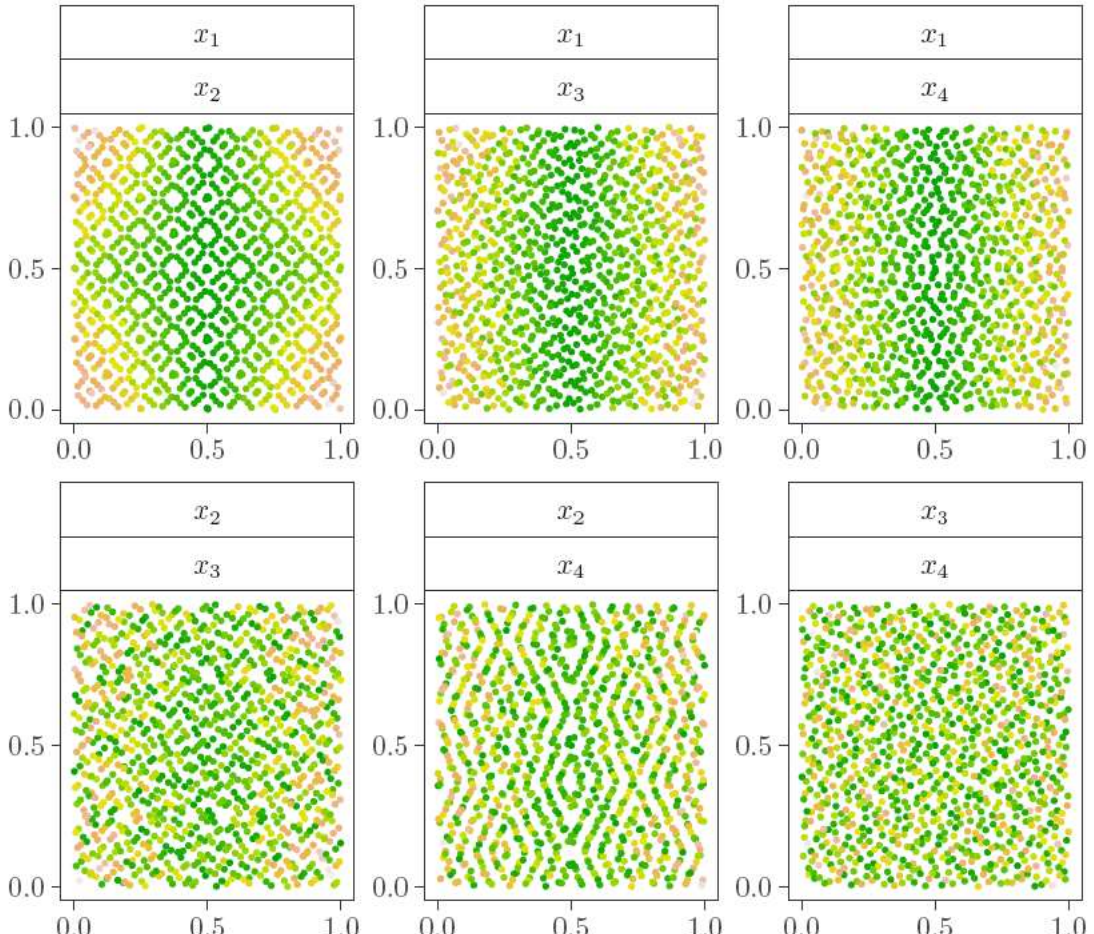
SALib https://salib.readthedocs.io/en/latest/

Journal of Statistical Software

Home / Archives / Vol. 102 (2022) / Issue 5

sensobol: An R Package to Compute Variance-Based Sensitivity Indices

Arnald Puy, Samuele Lo Piano, Andrea Saltelli, Simon A. Levin

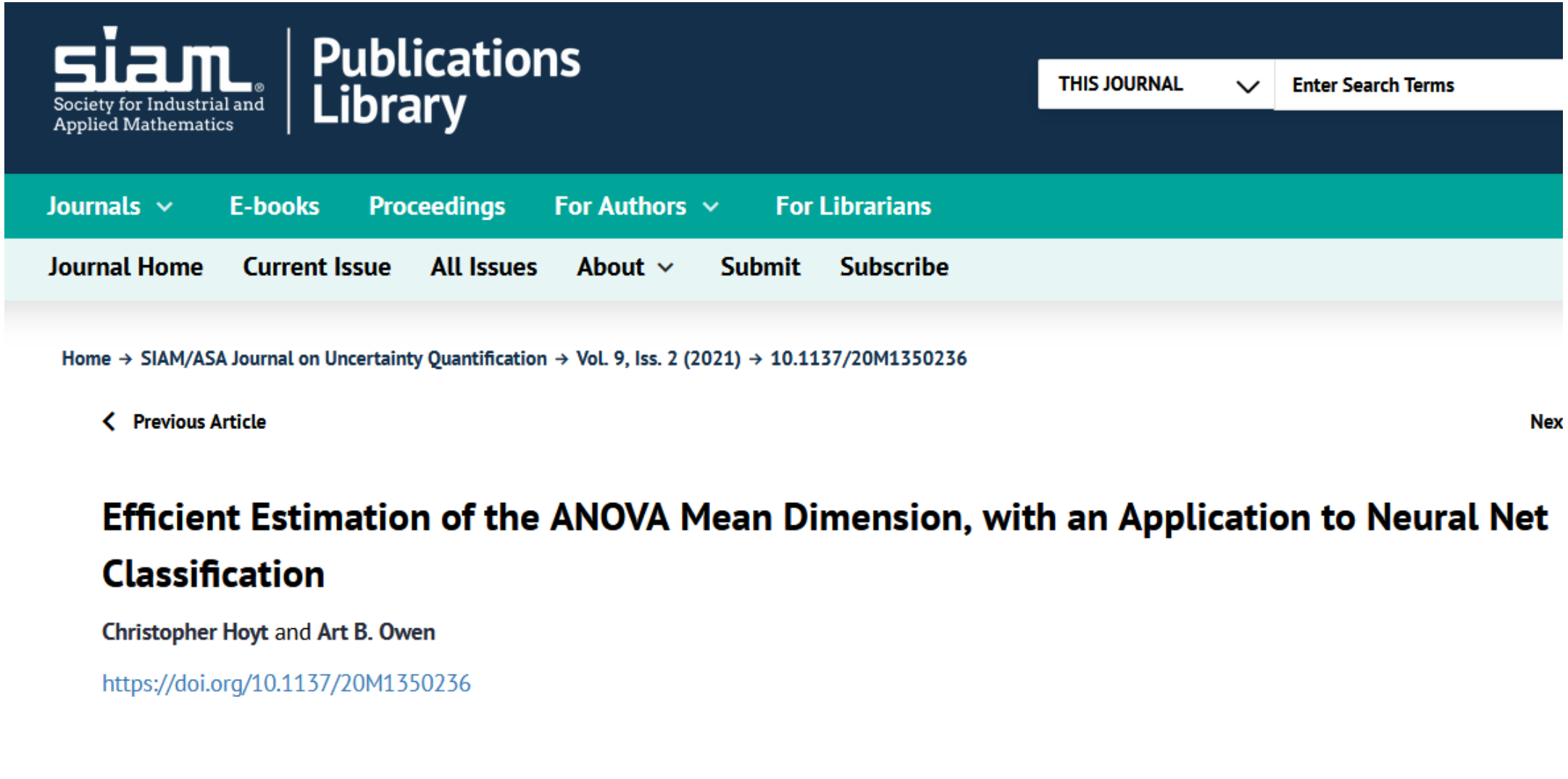


Model's effective dimension

The difficulty of a function/model is not in its number of dimensions but in the number of effective dimensions, either in the **truncation** or **superposition** sense

truncation sense = how many factors are important?
superposition sense=how high is the highest interaction?

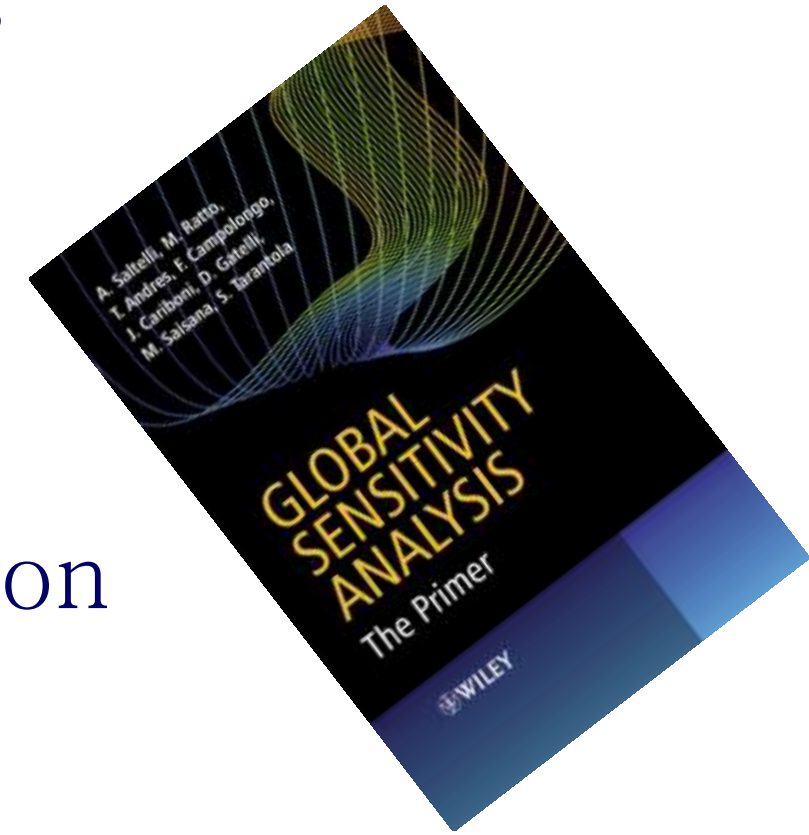
Or you can compute the mean dimension directly



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
- give the effective dimension



Chapter 1 its exercises

… anyone developing a
new method tests it against S_i, T_i

AGU PUBLICATIONS

Water Resources Research

RESEARCH ARTICLE

10.1002/2015WR017558

Companion to
Razavi and Gupta [2016],
doi:10.1002/2015WR017559.

Key Points:
- The VARS framework enables

A new framework for comprehensive, robust, and efficient global sensitivity analysis: 1. Theory

Saman Razavi[1,2] and Hoshin V. Gupta[3]

[1]Global Institute for Water Security & School of Environment and Sustainability, University of Saskatchewan, Saskatoon, Saskatchewan, Canada, [2]Department of Civil and Geological Engineering, University of Saskatchewan, Saskatoon, Saskatchewan, Canada, [3]Department of Hydrology and Water Resources, University of Arizona, Tucson, Arizona, USA

S_i, T_i can be used to do a sensitivity analysis of a sensitivity analysis…

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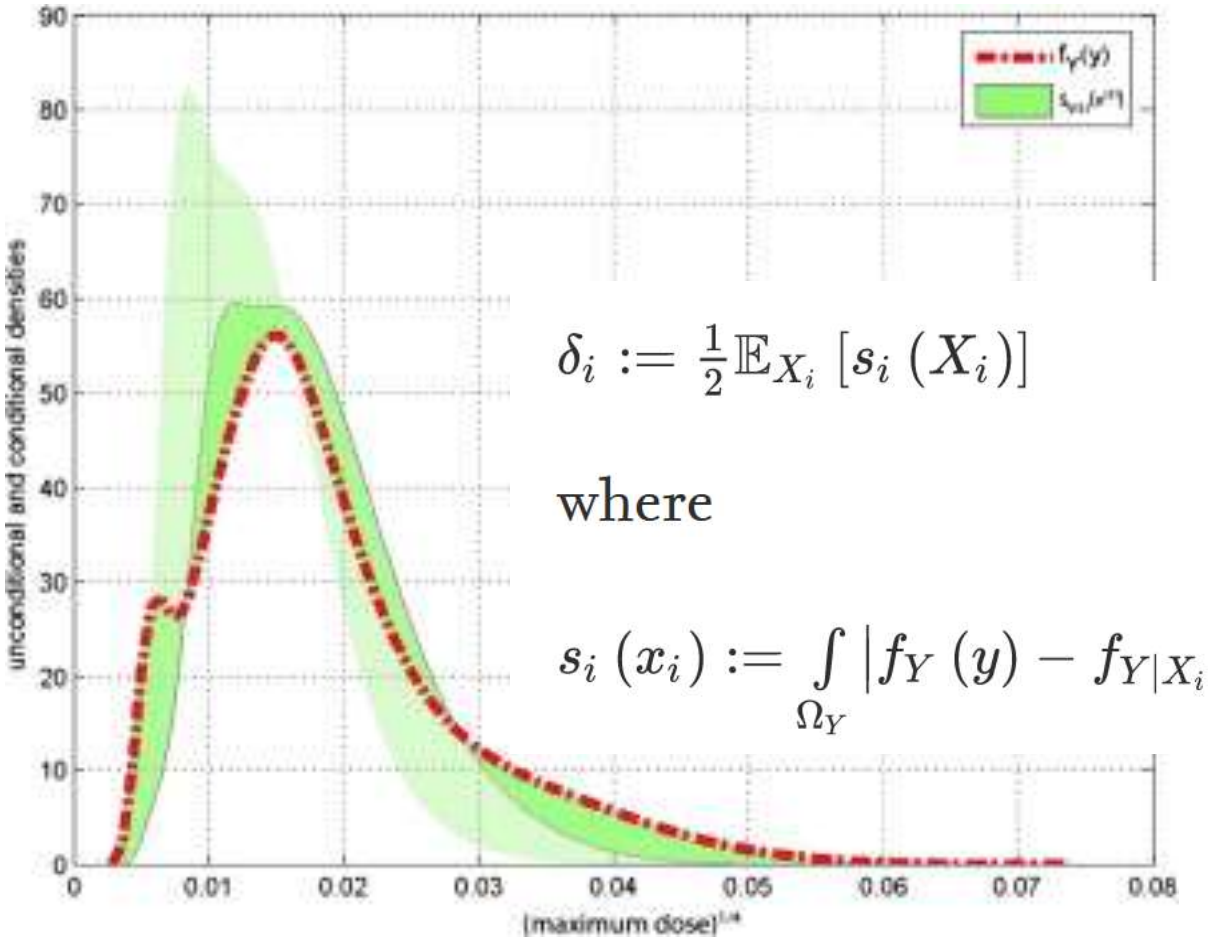
Environmental Modelling & Software

Volume 137, March 2021, 104960

Is VARS more intuitive and efficient than Sobol' indices?

Arnald Puy [a, b], Samuele Lo Piano [c], Andrea Saltelli [d]

… but there are other methods that can be used for different settings, e.g. moment independents methods, Shapley coefficients, reduced spaces, VARS …



$$\delta_i := \frac{1}{2}\mathbb{E}_{X_i}\left[s_i\left(X_i\right)\right]$$

where

$$s_i\left(x_i\right) := \int_{\Omega_Y} \left|f_Y\left(y\right) - f_{Y|X_i=x_i}\left(y\right)\right| dy$$

ELSEVIER

Environmental Modelling & Software

Volume 34, June 2012, Pages 105-115

Model emulation and moment-independent sensitivity analysis: An application to environmental modelling

E. Borgonovo [a], W. Castaings [b, c], S. Tarantola [d]

Don’t use One factor At a Time (OAT)

A geometric proof

Environmental Modelling & Software 25 (2010) 1508–1517

Contents lists available at ScienceDirect

Environmental Modelling & Software

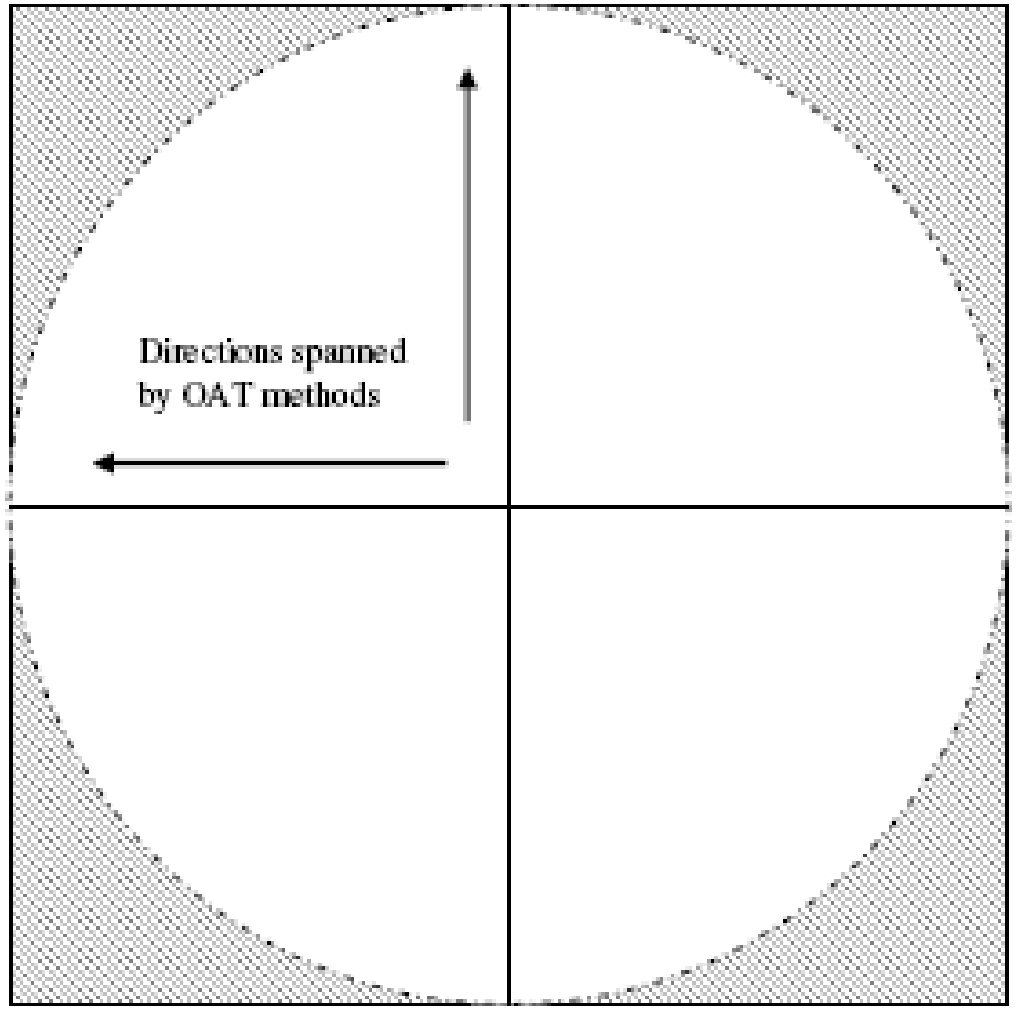
journal homepage: www.elsevier.com/locate/envsoft

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

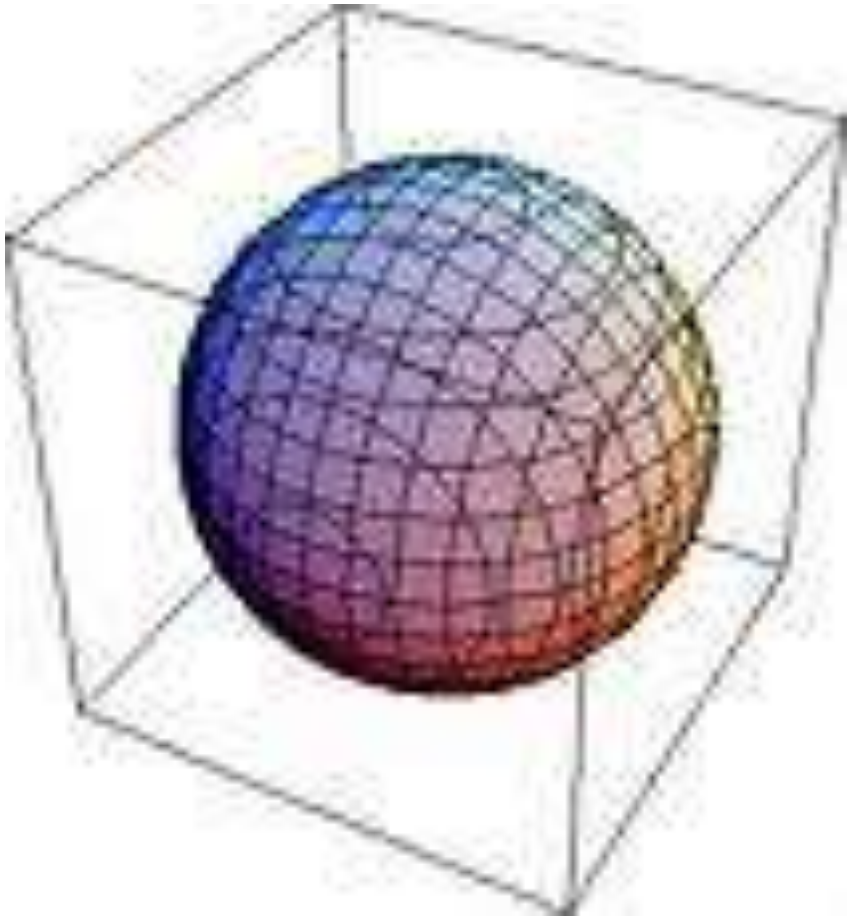
OAT in 2 dimensions



Area circle / area square =?

~ 3/4

OAT in 3 dimensions

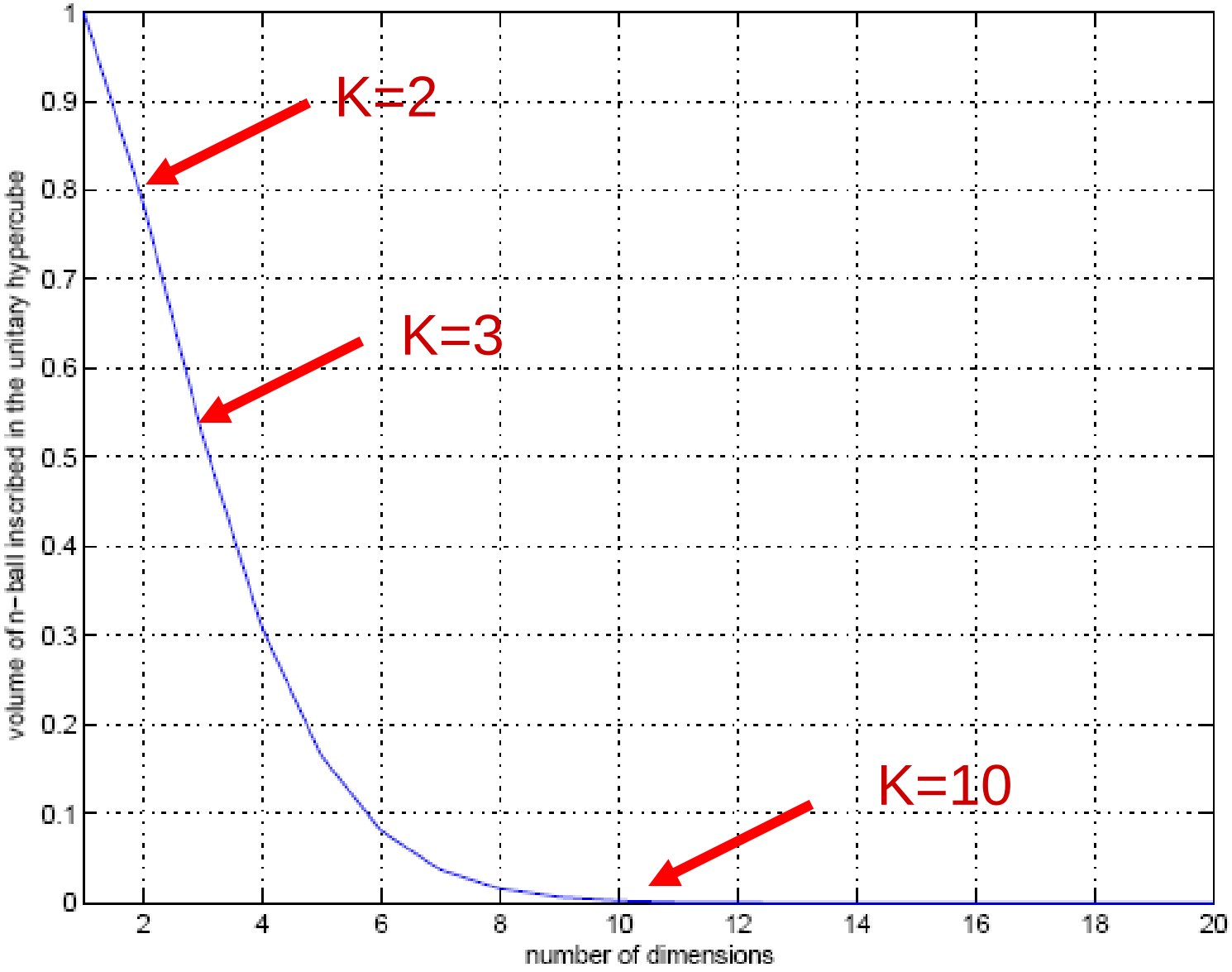


Volume sphere / volume cube =?

~ 1/2

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

OAT in k dimensions

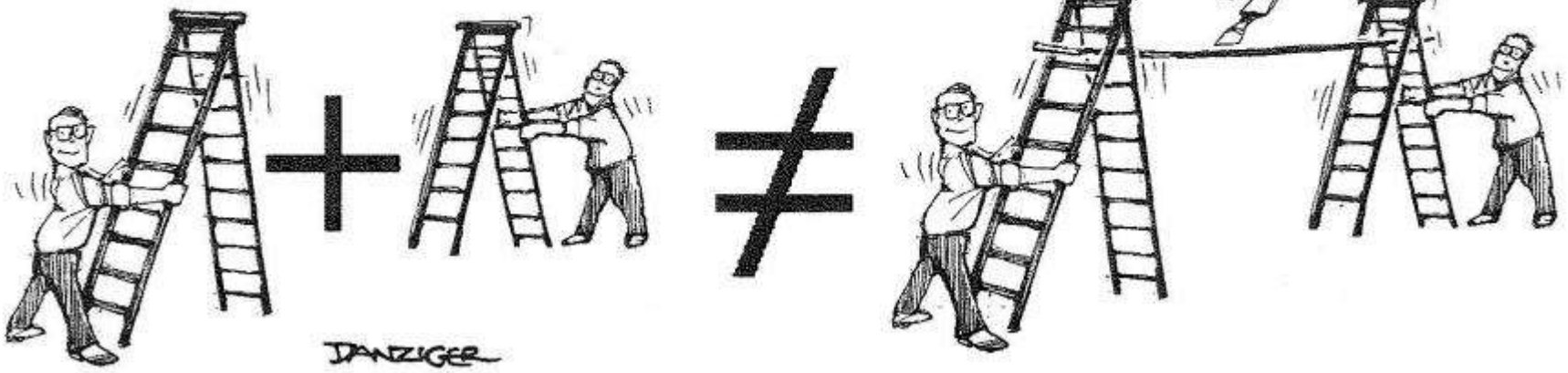


OAT does not capture interactions

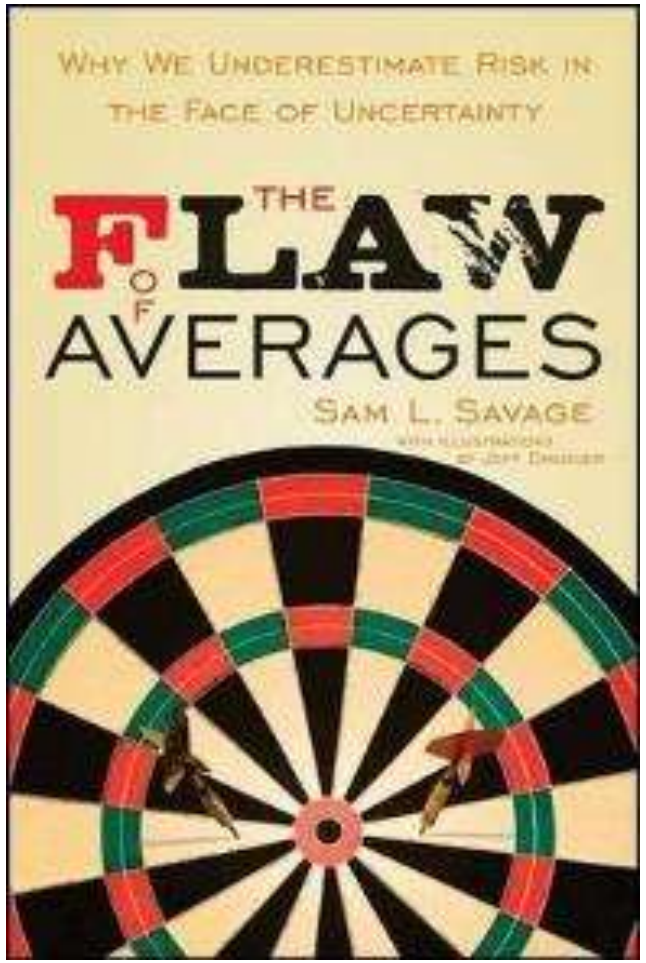
➔ The resulting analysis is non conservative

How would you test the scaffolding?

How coupled ladders are shaken in most of available literature



How to shake coupled ladders



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]

Don’t use method that are not model-independent (such as PCC, PRCC)

Use model-free methods

Why not using correlation-regression based techniques? PCC, PRCC, SRC, SRRC

Reliability Engineering & System Safety
Volume 28, Issue 2, 1990, Pages 229-253

Non-parametric statistics in sensitivity analysis for model output: A comparison of selected techniques

A. Saltelli, J. Marivoet

Computational Statistics & Data Analysis
Volume 13, Issue 1, January 1992, Pages 73-94

Sensitivity analysis for model output: Performance of black box techniques on three international benchmark exercises

A. Saltelli, T. Homma

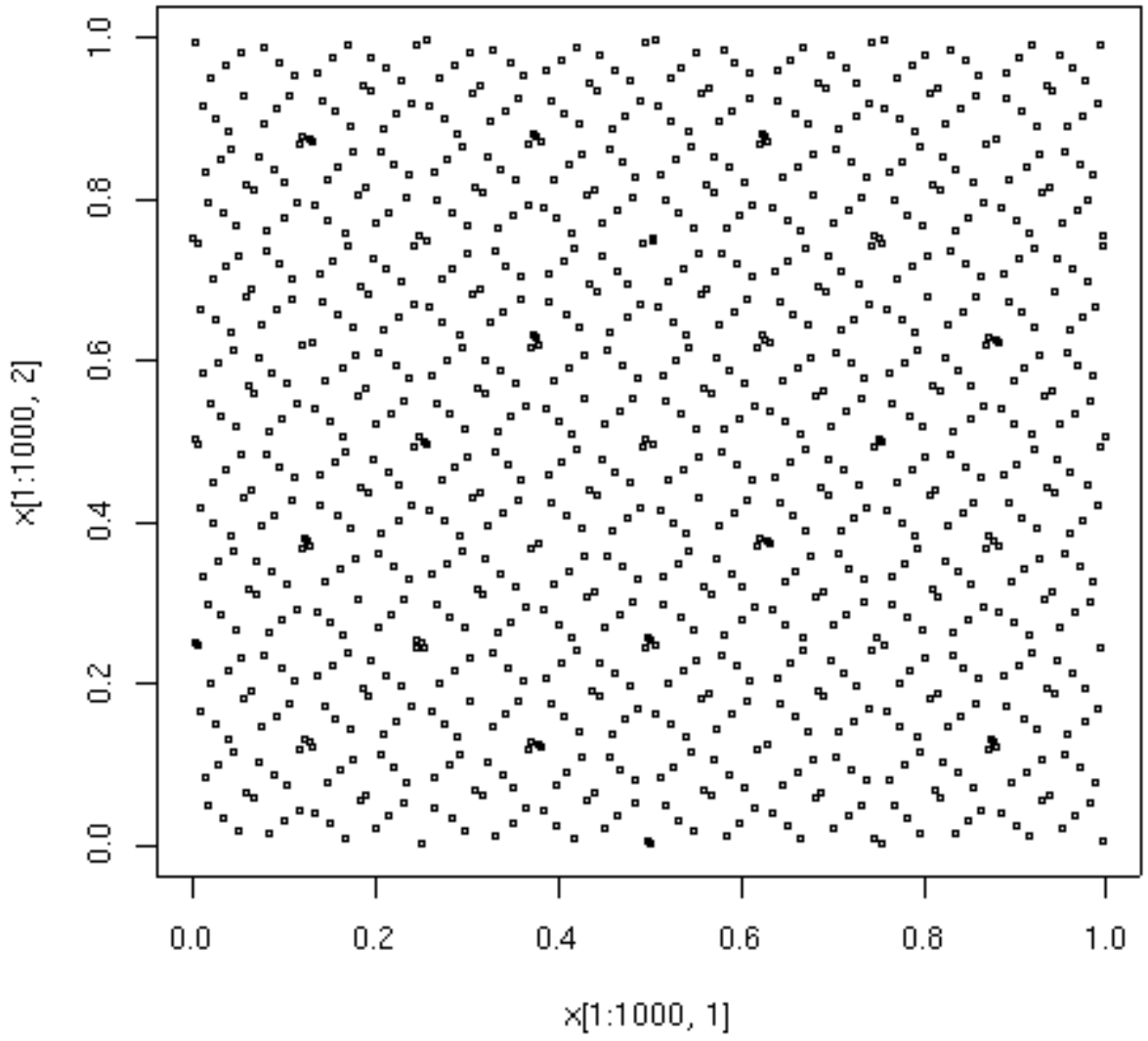
➔They assume linearity (PCC) or monotonicity (PRCC), which is difficult to know *ex-ante*

Don’t use either LHS or optimized LHS

Quasi-random sequences perform better

Quasi random sequences

Ilya M. Sobol’



Cornell University

the

arXiv.org > stat > arXiv:1505.02350

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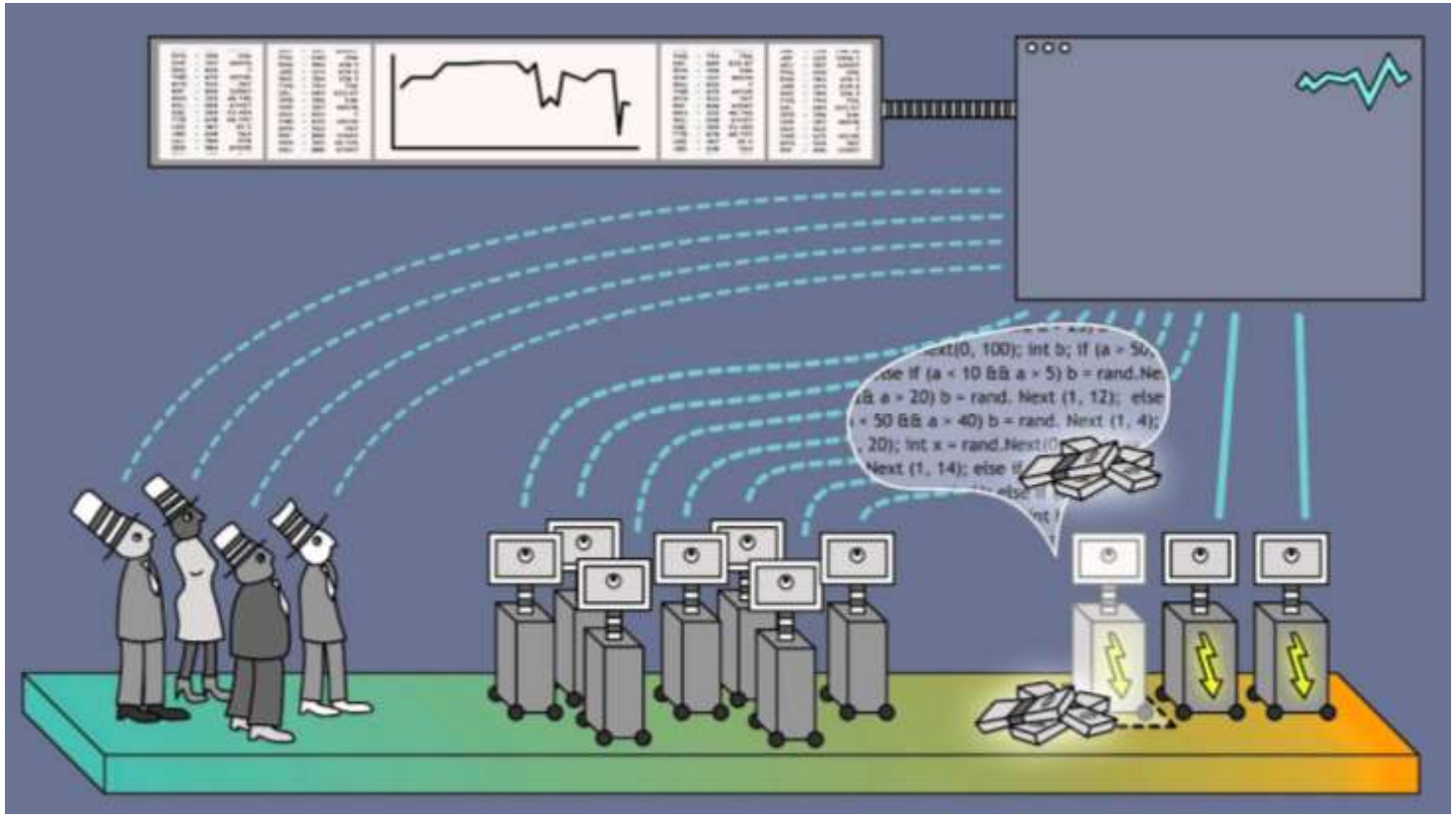
Statistics > Applications

[Submitted on 10 May 2015]

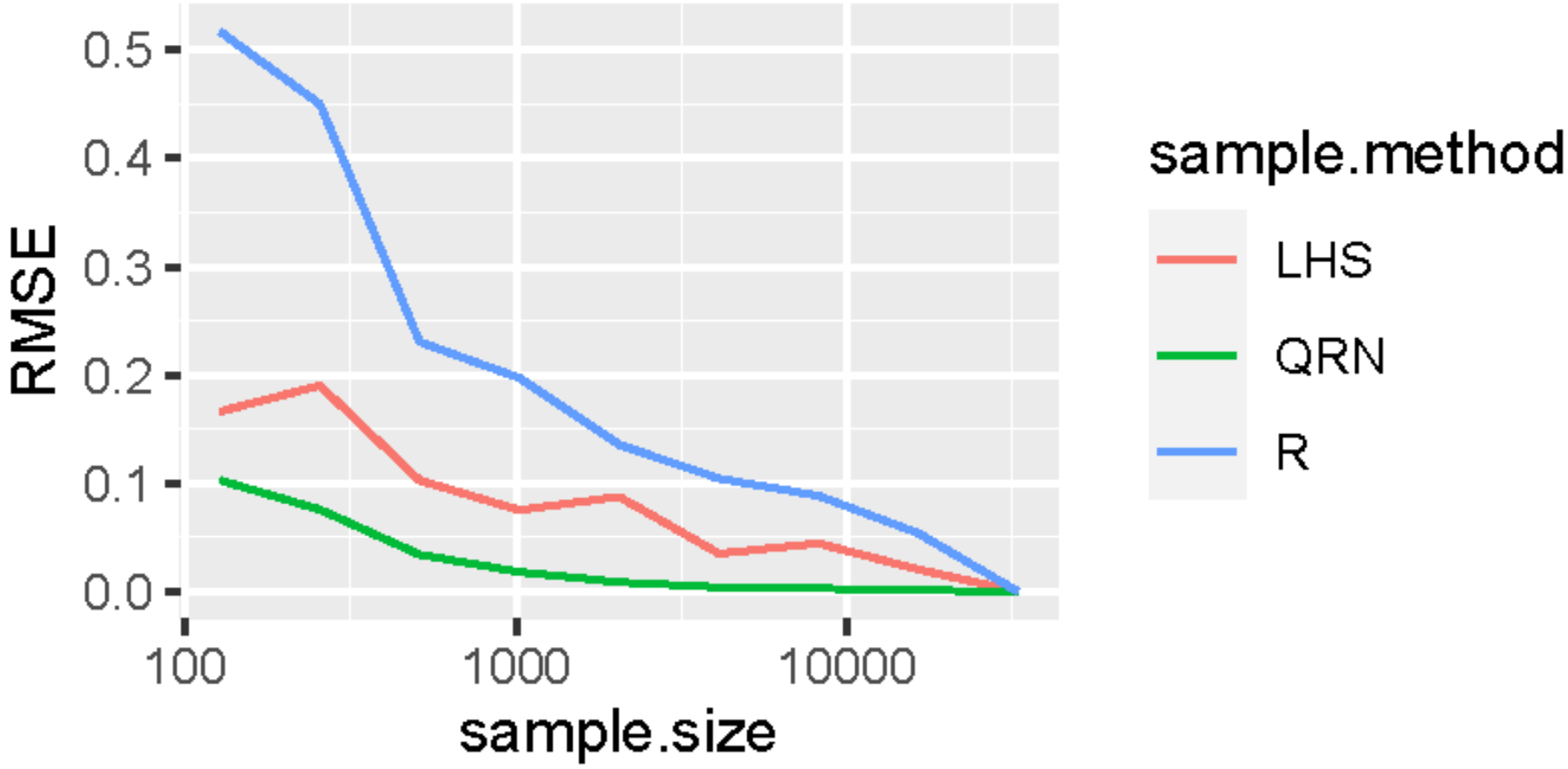
Exploring multi-dimensional spaces: a Comparison of Latin Hypercube and Quasi Monte Carlo Sampling Techniques

Sergei Kucherenko, Daniel Albrecht, Andrea Saltelli

Sobol' LP-TAU are used in high frequency trading



Source: https://www.youtube.com/watch?v=z4nCTdQlH8w



Root mean square error with different designs.

Work in progress with Arnald Puy (U. Birmingham)

Don’t run the model just once

There is much to learn by running the model
a few times, especially during model building

Lubarsky's Law of Cybernetic Entomology: there is always one more bug!

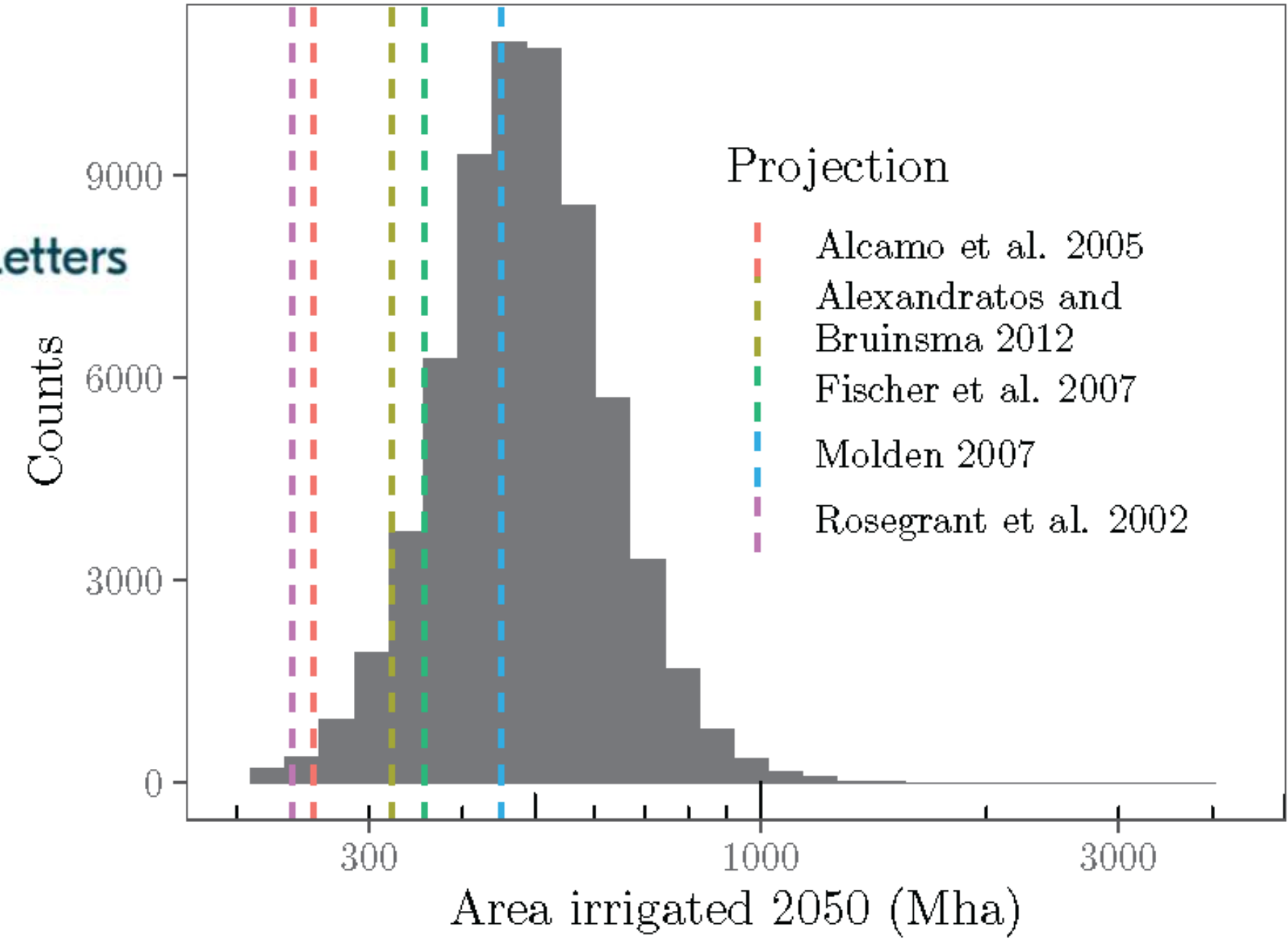
Model routinely used to produce point estimates may becomes non conservative when the uncertainty is plugged in

Current Models Underestimate Future Irrigated Areas

Geophysical Research Letters

A. Puy ✉, S. Lo Piano, A. Saltelli

Citation:
Puy, A., Lo Piano, S., & Saltelli, A. (2020). Current models underestimate future irrigated areas. *Geophysical Research Letters*, *47*, e2020GL087360. https://doi.org/10.1029/2020GL087360



nature communications

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The delusive accuracy of global irrigation water withdrawal estimates

Miscalculating the volumes of water withdrawn for irrigation, the largest consumer of freshwater in the world, jeopardizes sustainable water management. Hydrological models quantify water withdrawals, but their estimates are unduly precise. Model imperfections need to be appreciated to avoid policy misjudgements.

Sustainable Development Goals (SDGs), from Zero Hunger (SDG 2) to Water Stress (SDG 6), will be poorly assessed if irrigation water withdrawal convey an illusion of accuracy

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The delusive accuracy of global irrigation water withdrawal estimates

Arnald Puy, Razi Sheikholeslami, Hoshin V. Gupta, Jim W. Hall, Bruce Lankford, Samuele Lo Piano, Jonas Meier, Florian Pappenberger, Amilcare Porporato, Giulia Vico & Andrea Saltelli

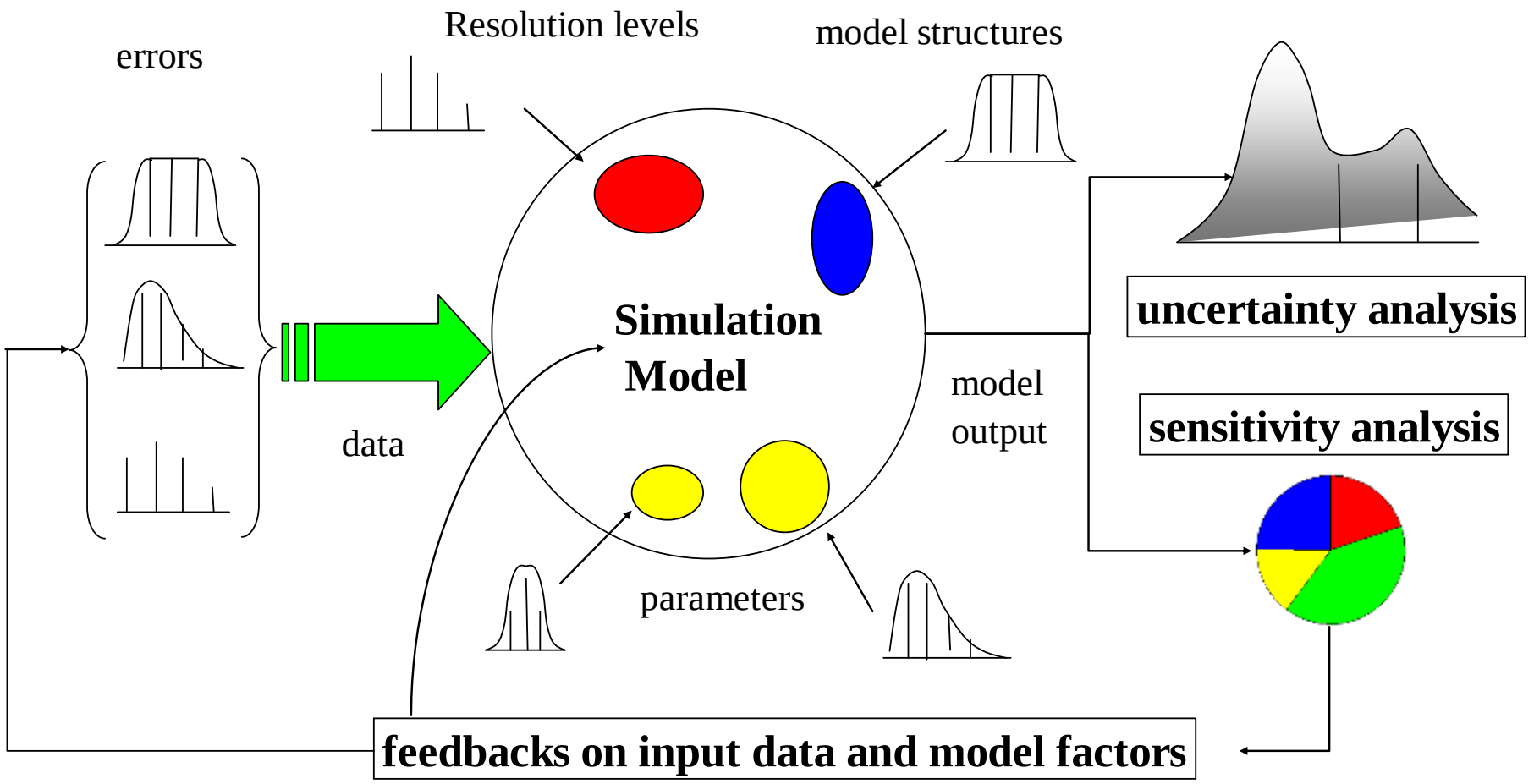
Solution? Modelling of the modelling process by taking ‘all paths in the garden’

Don’t sample just parameters and boundary conditions

Explore thoroughly the space of the assumptions

An engineer's vision of UA, SA

Remember?

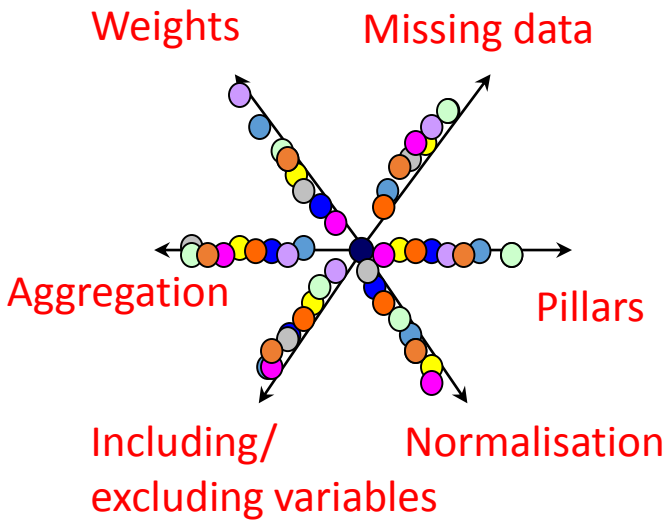


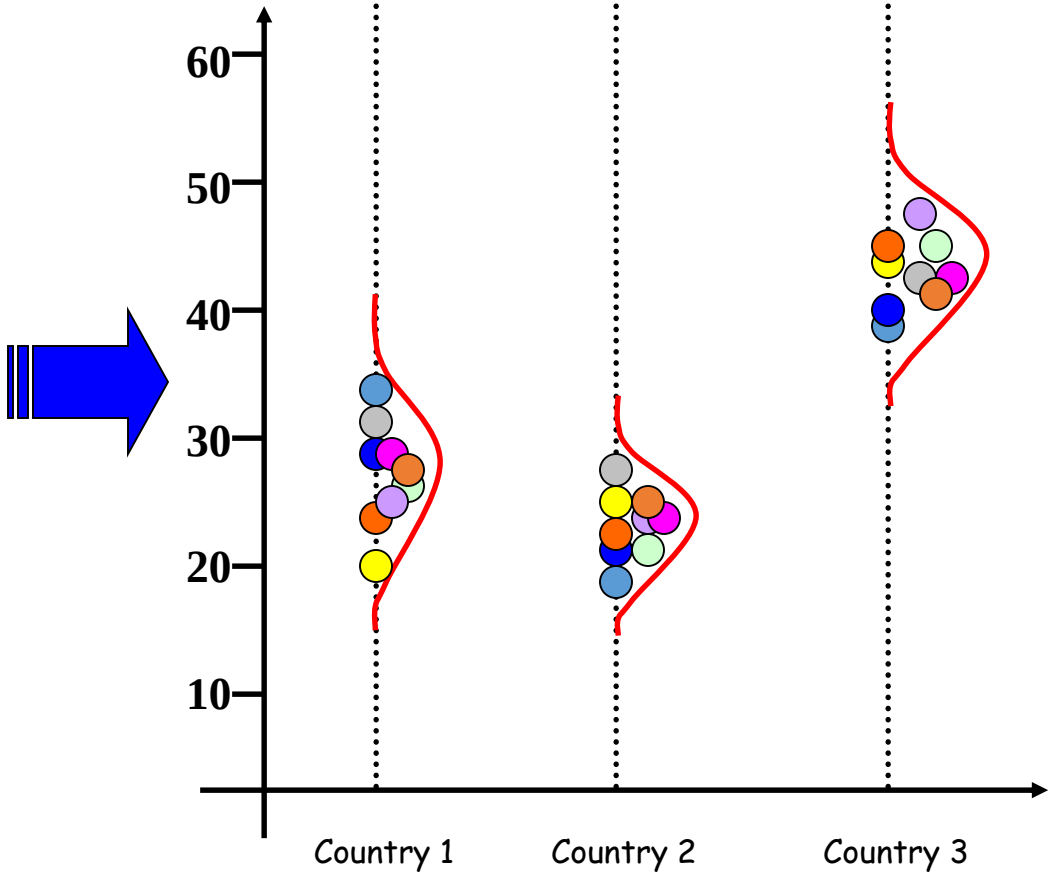
One can sample more than just factors:

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

Assumption	Alternatives
Number of indicators	▪ all six indicators included or one-at-time excluded (6 options)
Weighting method	▪ original set of weights, ▪ factor analysis, ▪ equal weighting, ▪ data envelopment analysis
Aggregation rule	▪ additive, ▪ multiplicative, ▪ Borda multi-criterion

Space of alternatives





Don’t go public with your results without having seen your SA

Find SA before SA finds you

NEVER vary all factors of the same amount

Be it 5%, 10%, or 20%

New WHO estimates: Up to 190 000 people could die of COVID-19 in Africa if not controlled

07 May 2020

Brazzaville – Eighty-three thousand to 190 000 people in Africa could die of COVID-19 and 29 million to 44 million could get infected in the first year of the pandemic if containment measures fail, a new study by the World Health Organization (WHO) Regional Office for Africa finds. The research, which is based on prediction modelling, looks at 47 countries in the

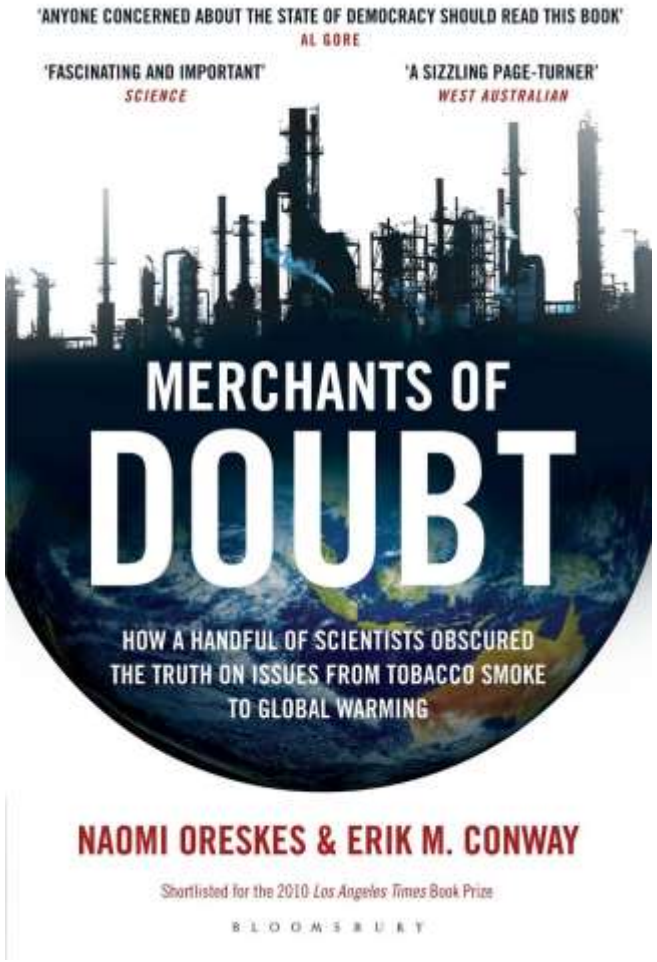
Speculative scenario in which ten uncertain input probabilities are increased by an arbitrary 10% — as if they were truly equally uncertain — with no theoretical or empirical basis for such a choice

World Health Organization
REGIONAL OFFICE FOR Africa

In a numerical experiment relating to a real-life application the range of uncertainty of each input is crucial input to the analysis, and often the most expensive to get

… beside uncertainty can be used instrumentally

… beside uncertainty can be used instrumentally; inflated by private interests, deflated by regulators



Futures

Available online 26 October 2021

In Press, Journal Pre-proof ?

Science, the endless frontier of regulatory capture

Andrea Saltelli [a] ✉, Dorothy J. Dankel [b, c], Monica Di Fiore [d], Nina Holland [e], Martin Pigeon [e]

The End