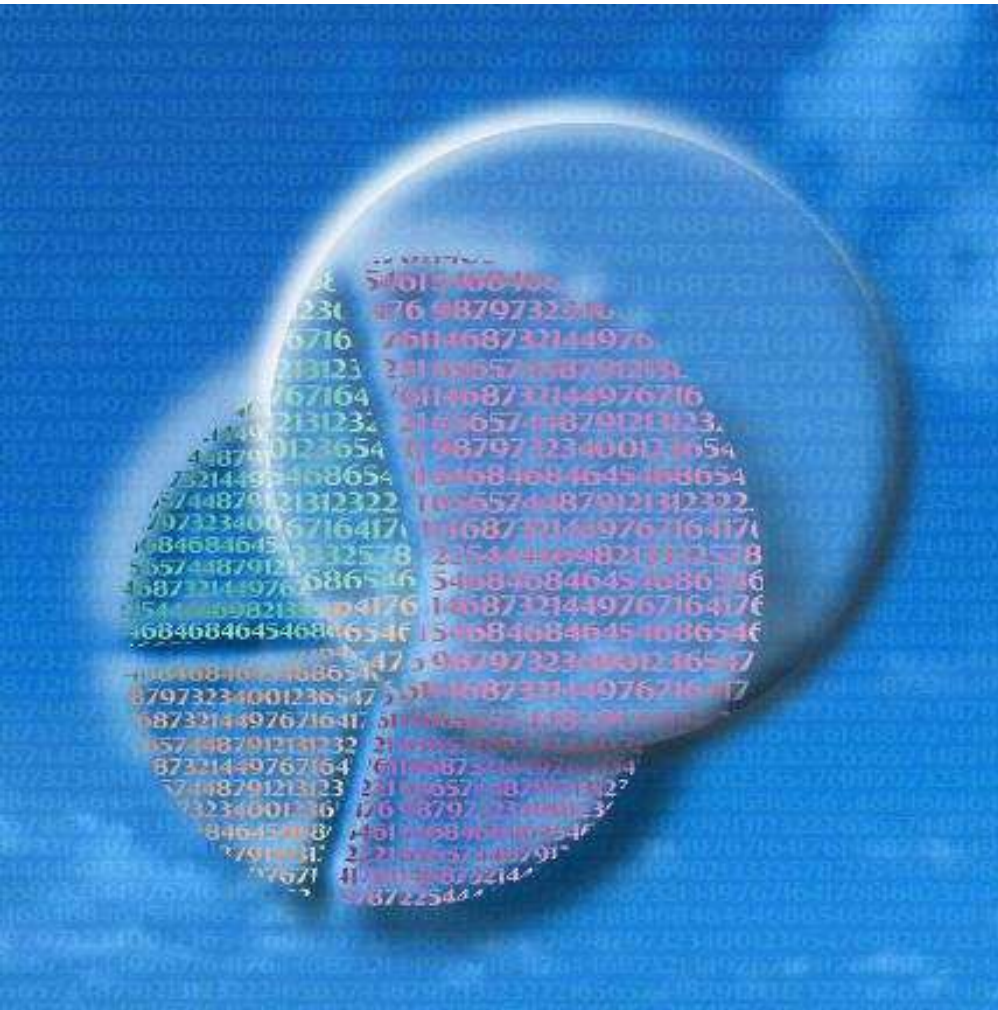


# Sensitivity analysis, in pills

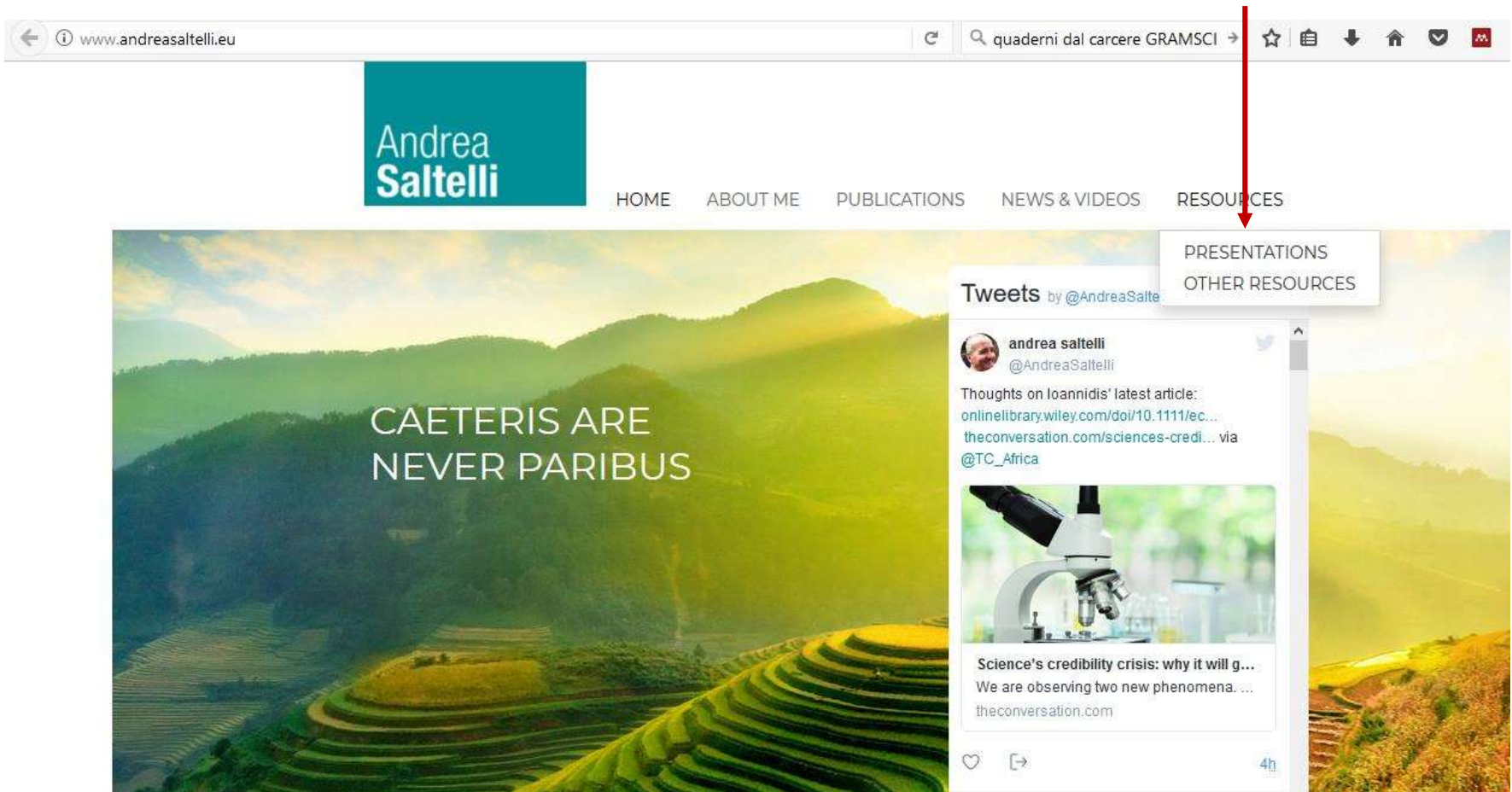
Andrea Saltelli

Centre for the Study of the  
Sciences and the Humanities  
(SVT), University of Bergen  
(UIB)

Seminar on Robustification of  
the Regional Payments  
Databases,  
24 November 24 2017  
Universitat Oberta de  
Catalunya, Tibidabo, Barcelona



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



The screenshot shows the homepage of the website [www.andreasaltelli.eu](http://www.andreasaltelli.eu). The browser's address bar at the top displays the URL. The website's header features a teal square with the name "Andrea Saltelli" in white. Below this, a navigation menu includes the following items: HOME, ABOUT ME, PUBLICATIONS, NEWS & VIDEOS, and RESOURCES. A red arrow points from the "RESOURCES" link to a dropdown menu that contains two options: "PRESENTATIONS" and "OTHER RESOURCES". The main content area of the website has a background image of terraced rice fields in a valley. Overlaid on the left side of this image is the Latin phrase "CAETERIS ARE NEVER PARIBUS" in white capital letters. On the right side, there is a section titled "Tweets by @AndreaSalte" which displays a tweet from the user "andrea saltelli" (@AndreaSaltelli). The tweet text reads: "Thoughts on Ioannidis' latest article: [onlinelibrary.wiley.com/doi/10.1111/ec...](https://onlinelibrary.wiley.com/doi/10.1111/ec...) [theconversation.com/sciences-credi...](https://theconversation.com/sciences-credi...) via @TC\_Africa". Below the text is a small image of a microscope. The tweet is timestamped "4h".

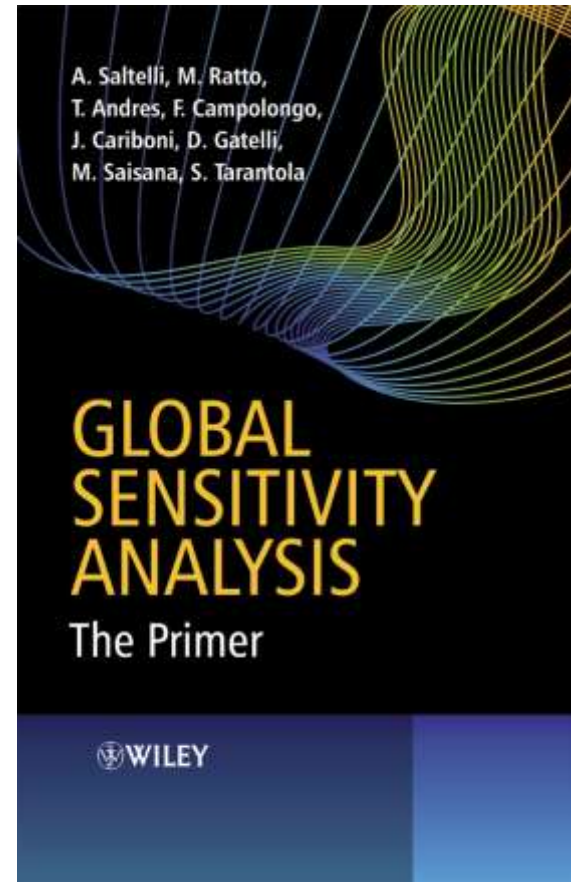
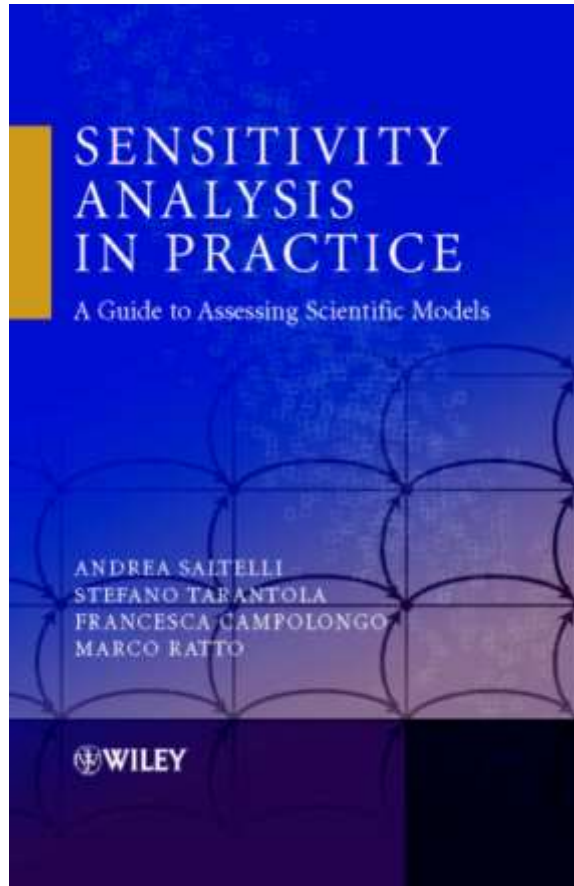


= more material on my web site



= discussion time

# Sensitivity analysis books available on LibGen



What is sensitivity  
analysis?



# Definitions

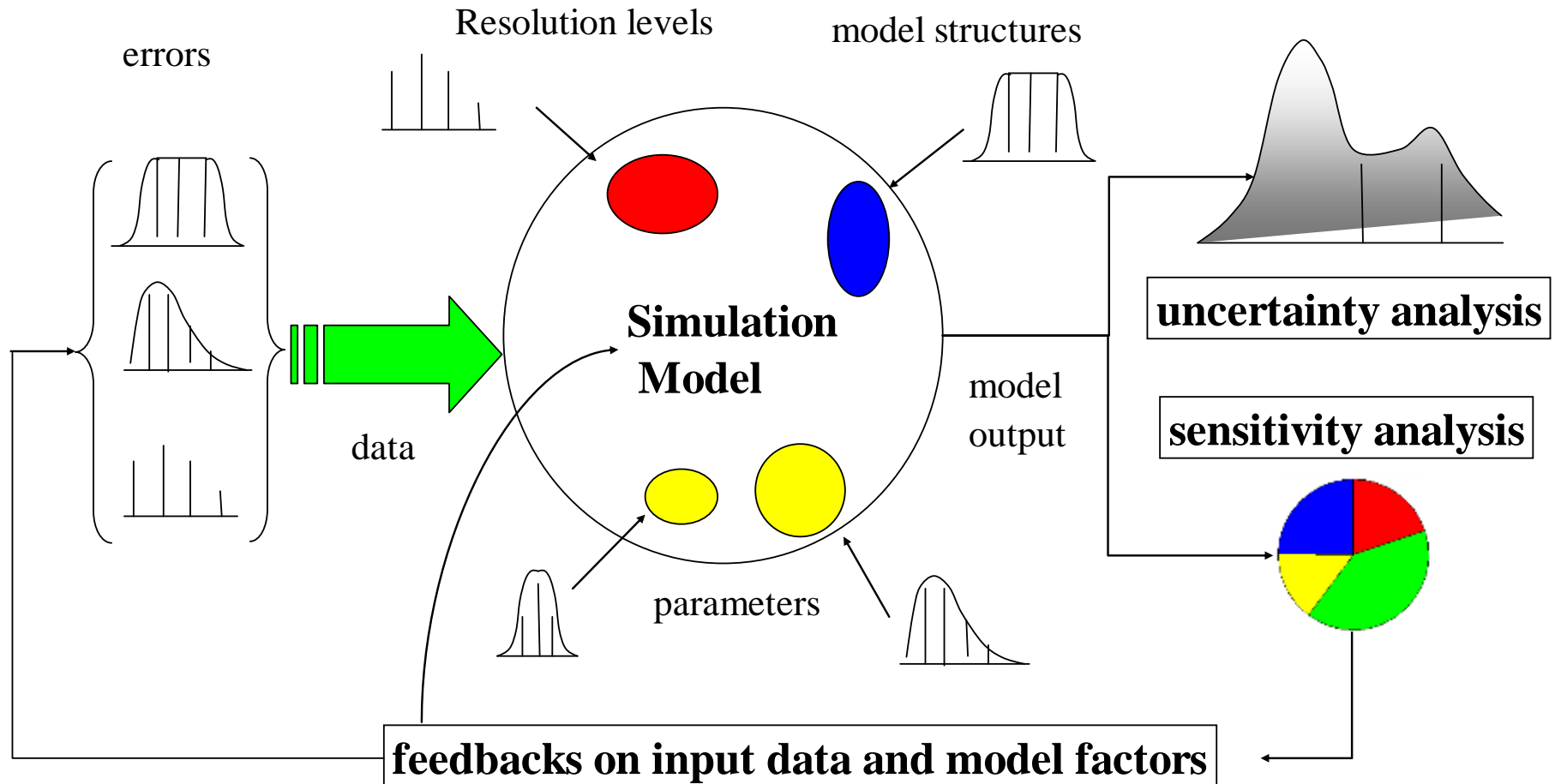
**Uncertainty analysis:** Focuses on just quantifying the uncertainty in model output

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

[Global\*] sensitivity analysis: “The study of how the uncertainty in the output of a model (numerical or otherwise) can be apportioned to different sources of uncertainty in the model input”

Saltelli A., 2002, Sensitivity Analysis for Importance Assessment, Risk Analysis, 22 (3), 1–12.

# An engineer's vision of UA, SA





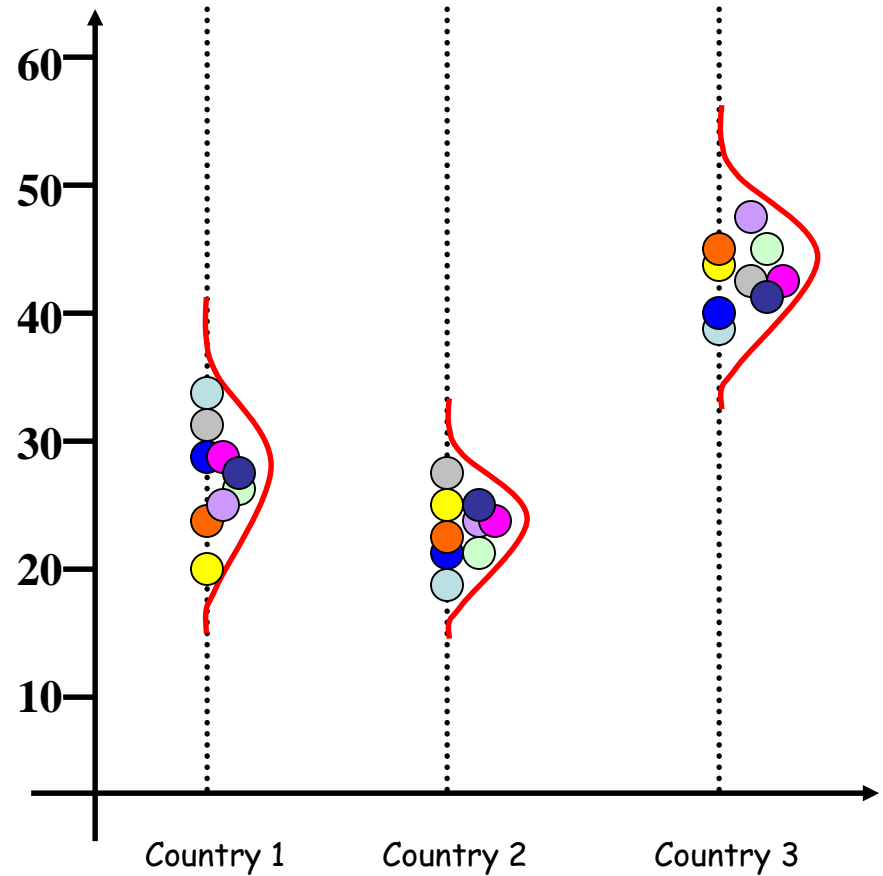
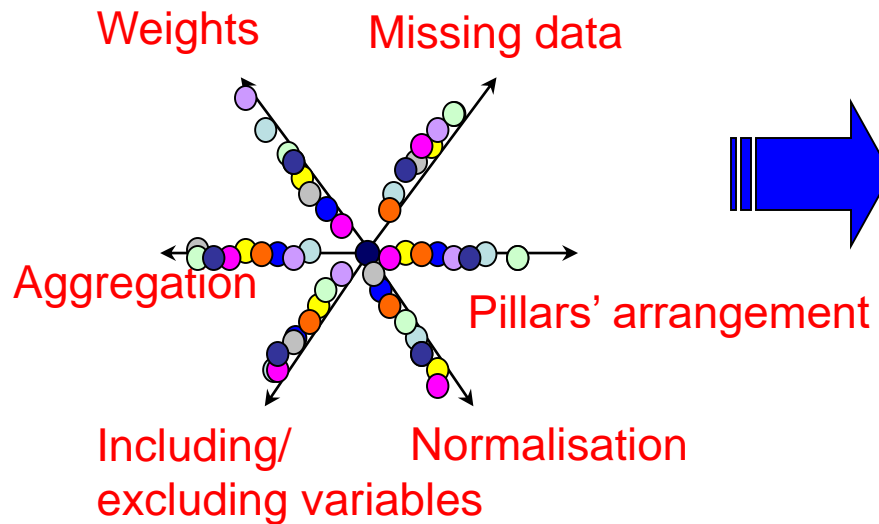
One can sample more than just factors

One can sample modelling assumptions

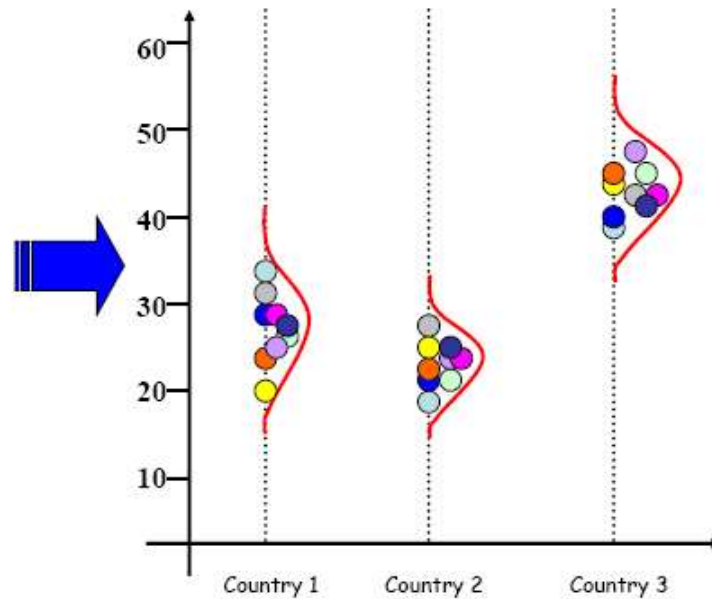
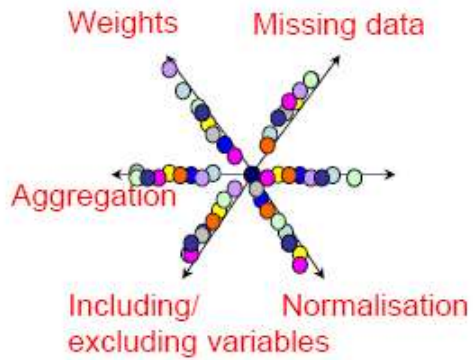
Example: The output is a composite indicator

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

## Space of alternatives

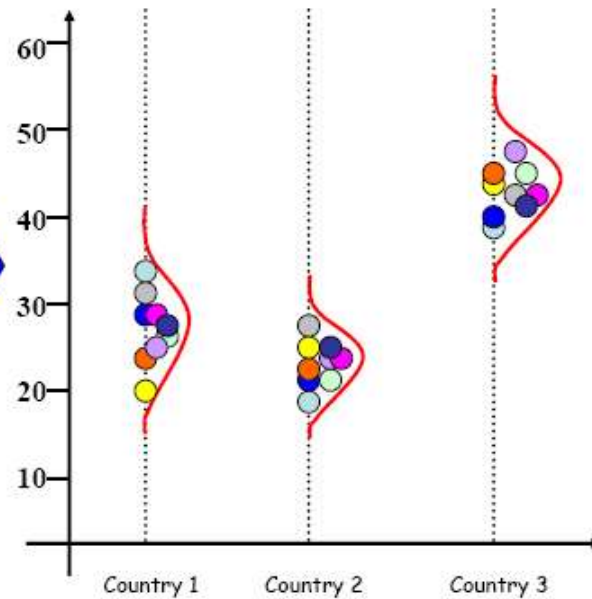
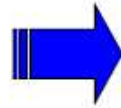
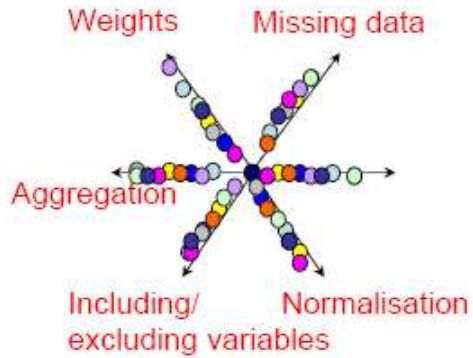


## Space of alternatives



Is this an uncertainty analysis or a sensitivity analysis?

## Space of alternatives



If I did a sensitivity analysis what information would I obtain?

Why Sensitivity analysis?

# 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?Dockey=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](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](https://www.whitehouse.gov/sites/default/files/omb/assets/omb/inforeg/proposed_risk_assessment_bulletin_010906.pdf), pp. 16–17, accessed December 2015.



<http://ec.europa.eu/smart-regulation/>



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 both the uncertainty of the prediction and the relative importance of variables.

p. 392

... where there is a major disagreement among stakeholders about the nature of the problem, ... then **sensitivity auditing** is more suitable but sensitivity analysis is still advisable as one of the steps of sensitivity auditing

p. 393

“In particular, one should avoid giving the impression of false confidence by “quantification at all costs”. In some cases there is simply not enough data, or the process is too complex, to give a meaningful quantitative prediction.”

# Sensitivity auditing

Saltelli, A., Guimarães Pereira, Â., Van der Sluijs, J.P. and Funtowicz, S., 2013, What do I make of your latinorum? Sensitivity auditing of mathematical modelling, Int. J. Foresight and Innovation Policy, 9, 2/3/4, 213–234.

Saltelli, A., Funtowicz, S., When all models are wrong: More stringent quality criteria are needed for models used at the science–policy interface, Issues in Science and Technology, Winter 2014, 79–85.

<http://issues.org/30-2/andrea/>



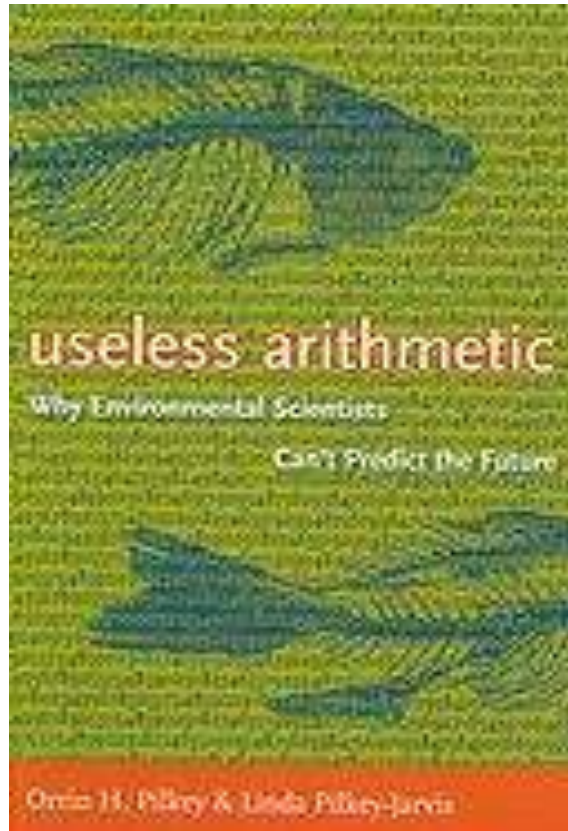
# Limits of sensitivity analysis



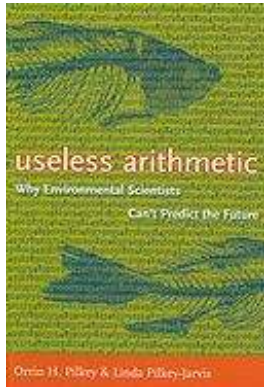
Orrin H. Pilkey  
Duke University,  
NC

# Useless Arithmetic: Why Environmental Scientists Can't Predict the Future

by Orrin H. Pilkey and Linda  
Pilkey-Jarvis





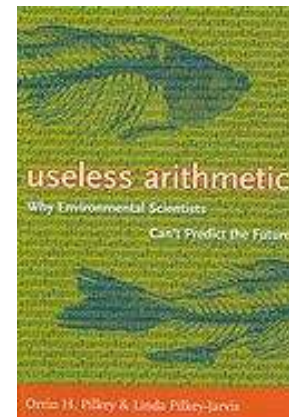


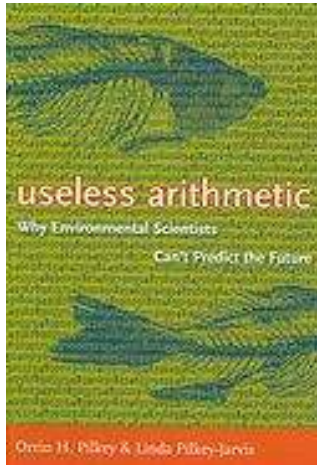
<<It is important, however, to recognize that the sensitivity of the parameter in the equation is what is being determined, not the sensitivity of the parameter in nature.

[...] 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.

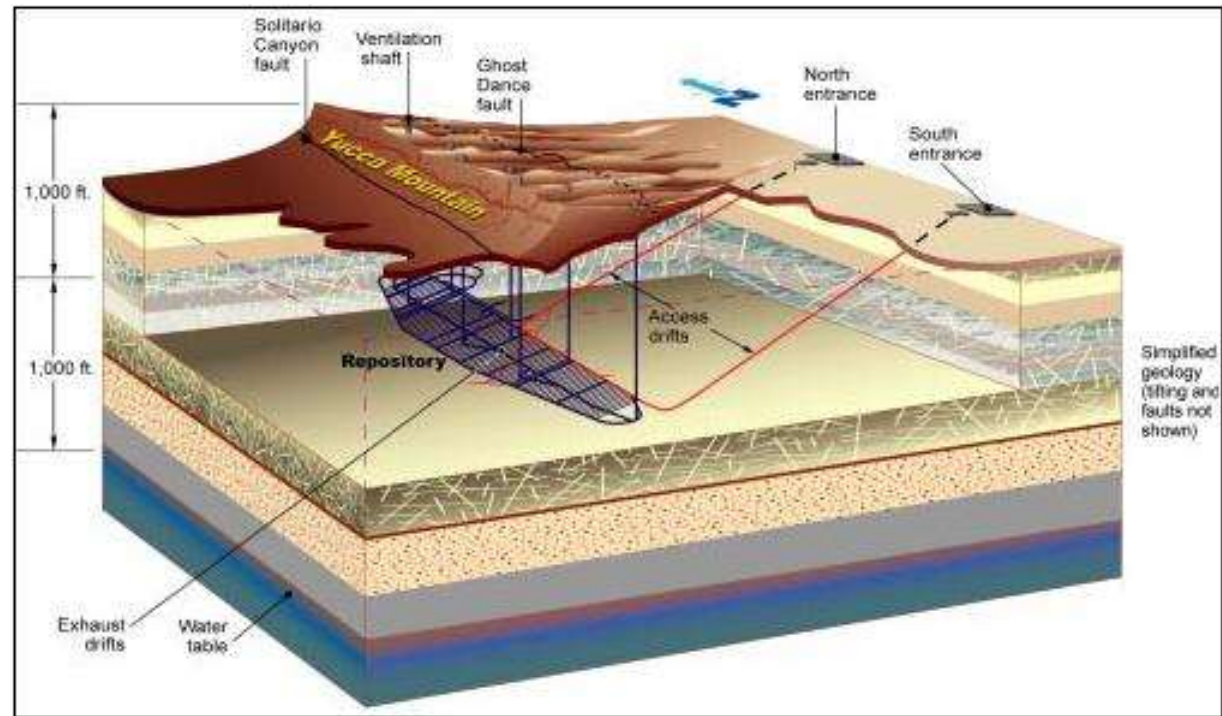
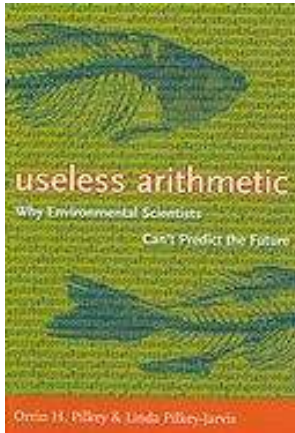
TSPA is Composed of 286 sub-models.





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.





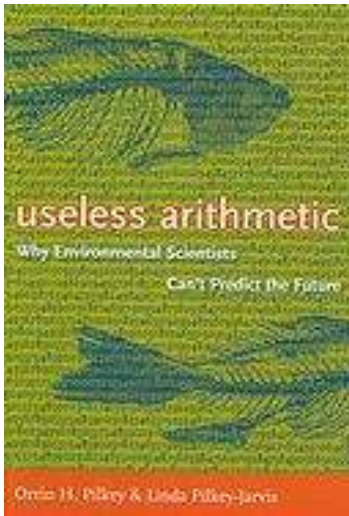
The confidence of the stakeholders in TSPA was not helped when evidence was produced which could lead to an upward revision of 4 orders of magnitude of this parameter (the  $^{36}\text{Cl}$  story)

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”

Ref. ➔ Robert K. Merton’s ‘Organized skepticism’



**Communalism** – the common ownership of scientific discoveries, according to which scientists give up intellectual property rights in exchange for recognition and esteem (Merton actually used the term Communism, but had this notion of communalism in mind, not Marxism);

**Universalism** – according to which claims to truth are evaluated in terms of universal or impersonal criteria, and not on the basis of race, class, gender, religion, or nationality;

**Disinterestedness** – according to which scientists are rewarded for acting in ways that outwardly appear to be selfless;

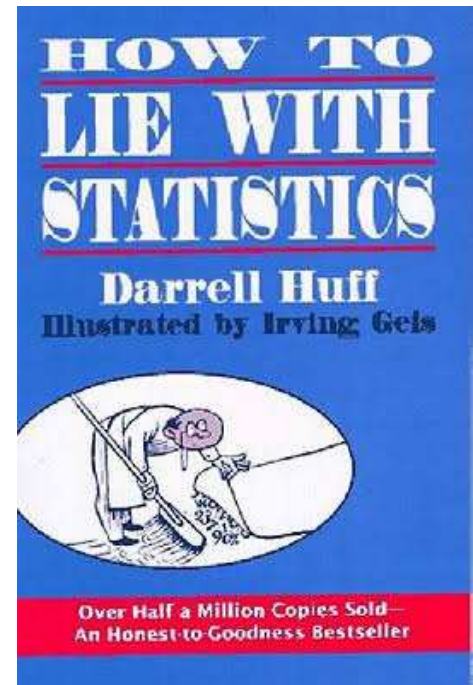
**Organized Skepticism** – all ideas must be tested and are subject to rigorous, structured community scrutiny.

Robert K. Merton

Can I lie with  
sensitivity  
analysis?



Will any sensitivity analysis do the job? Can I lie with sensitivity analysis as I can lie with statistics?



Saltelli, A., Annoni P., 2010, How to avoid a perfunctory sensitivity analysis, *Environmental Modeling and Software*, **25**, 1508–1517.

# Why not just changing one factor at a time (OAT)?

<<“one-at-a-time” (OAT) approach is most commonly used in Commission IAs>>

Source: IA Toolbox, p. 391

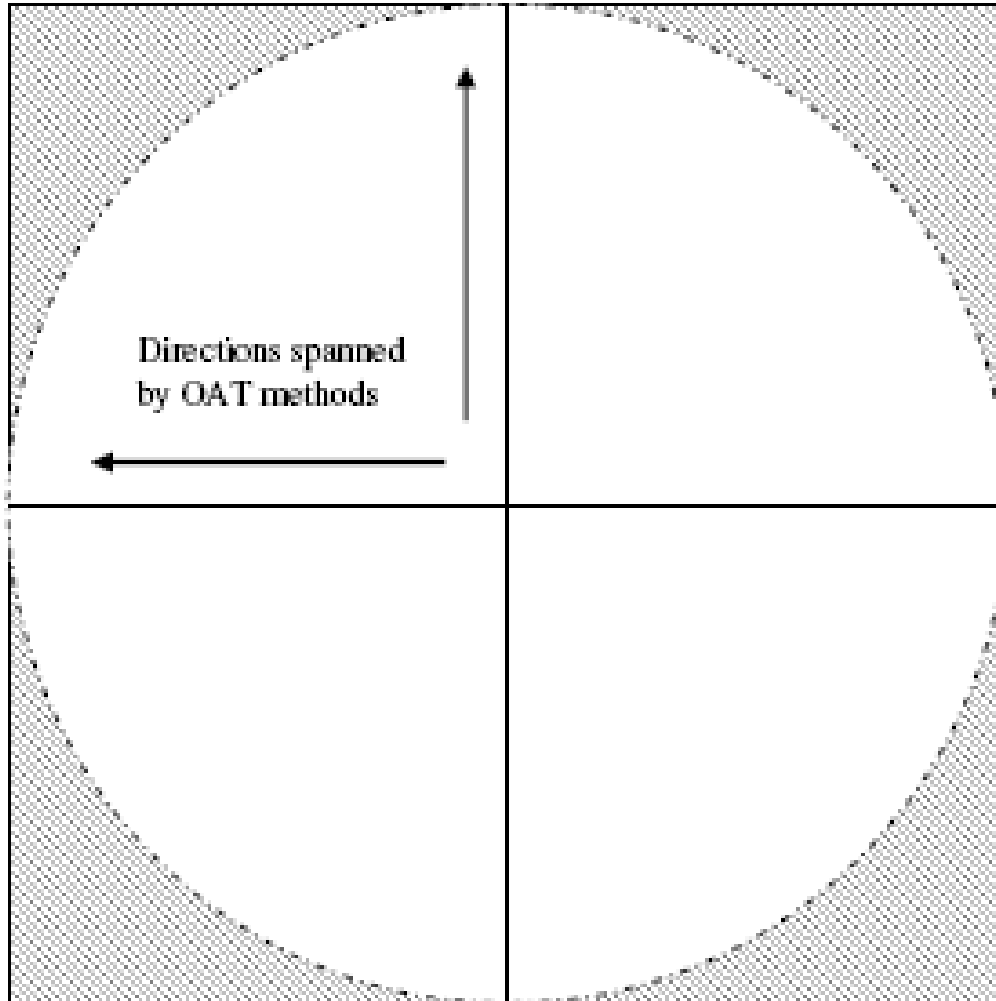


*Better Regulation "Toolbox"*

Why not just changing one factor  
at a time (OAT)?

Because it is a bad idea!

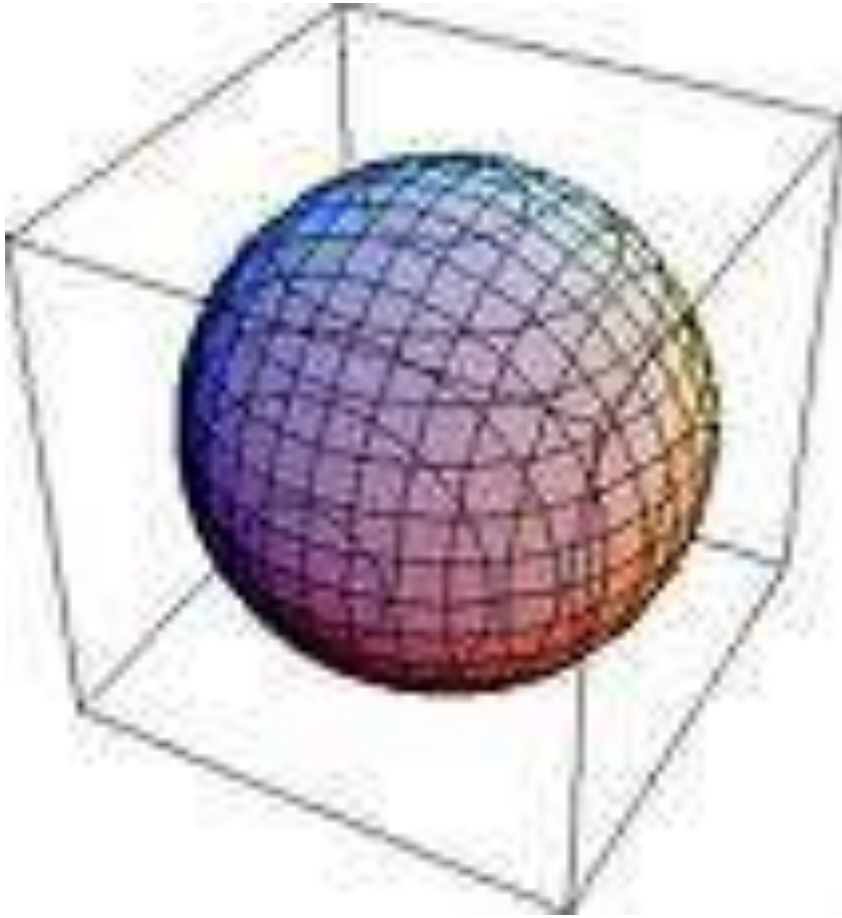
# OAT in 2 dimensions



Area circle / area  
square = ?

$\sim 3/4$

# OAT in 3 dimensions



Volume sphere /  
volume cube =?

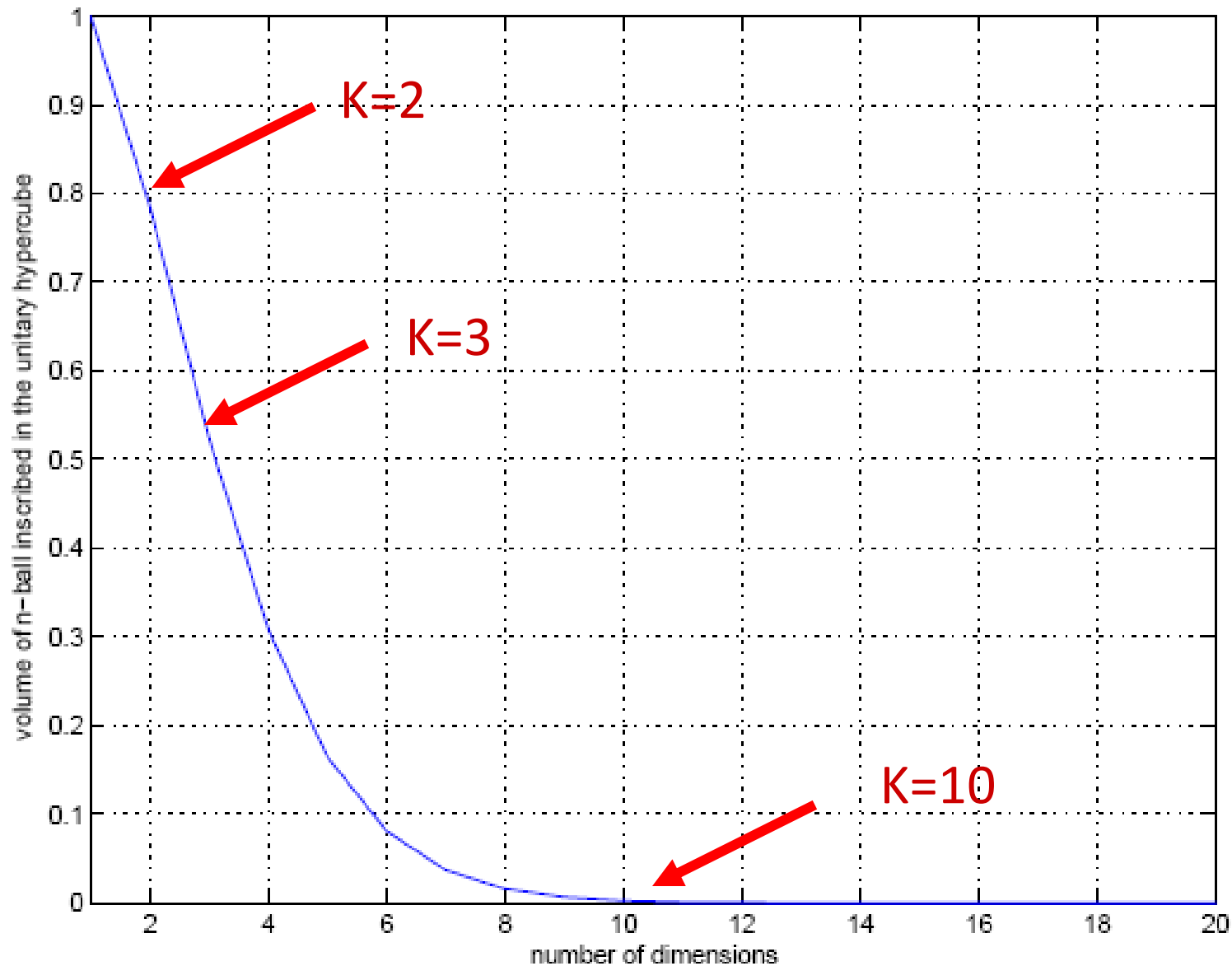
$\sim 1/2$

# OAT in 10 dimensions

Volume hypersphere / volume ten  
dimensional hypercube =? ~ 0.0025



# OAT in $k$ dimensions





Bottom-line: once a sensitivity analysis is done via OAT there is no guarantee that either uncertainty analysis (UA) or sensitivity analysis (SA) is any good:

- ➔ UA will be non conservative
- ➔ SA may miss important factors

# OAT is still the most largely used technique in SA.

Ferretti, F., Saltelli A., Tarantola, S., 2016, Trends in Sensitivity Analysis practice in the last decade, Science of the Total Environment, <http://dx.doi.org/10.1016/j.scitotenv.2016.02.133>

## Discussion points



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

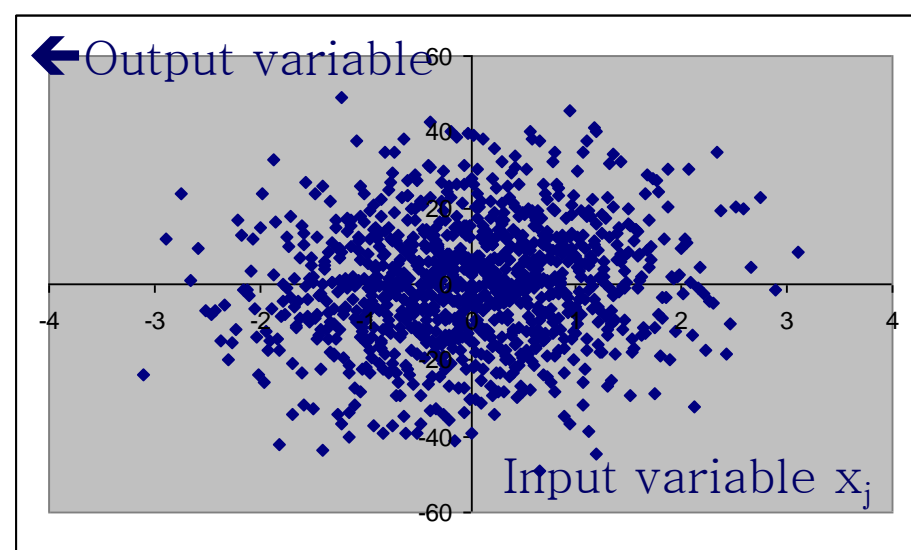
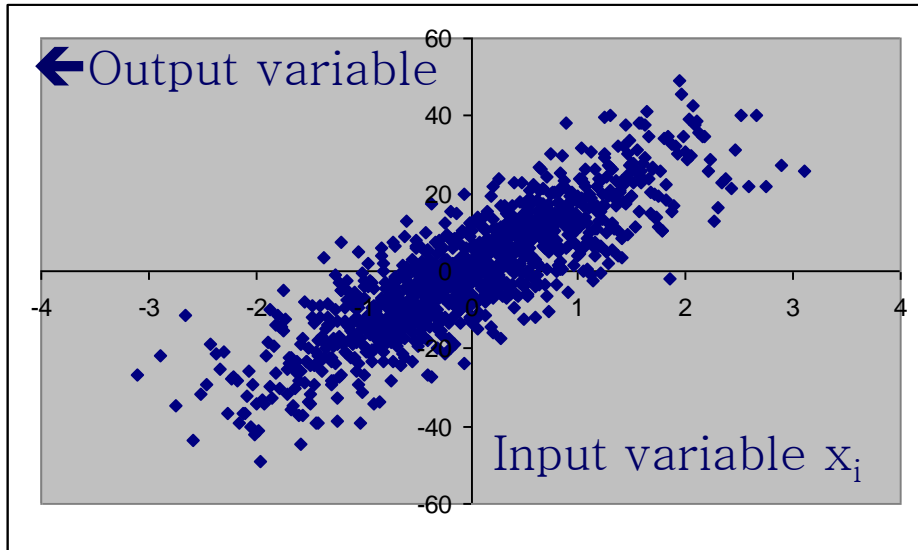
- Is something wrong about the statement above (p. 384 of EC guidelines)

Skipping:

Theory of variance based methods –  
Cooping with interactions

Other methods: Moment independent  
methods, Monte Carlo filtering, ...

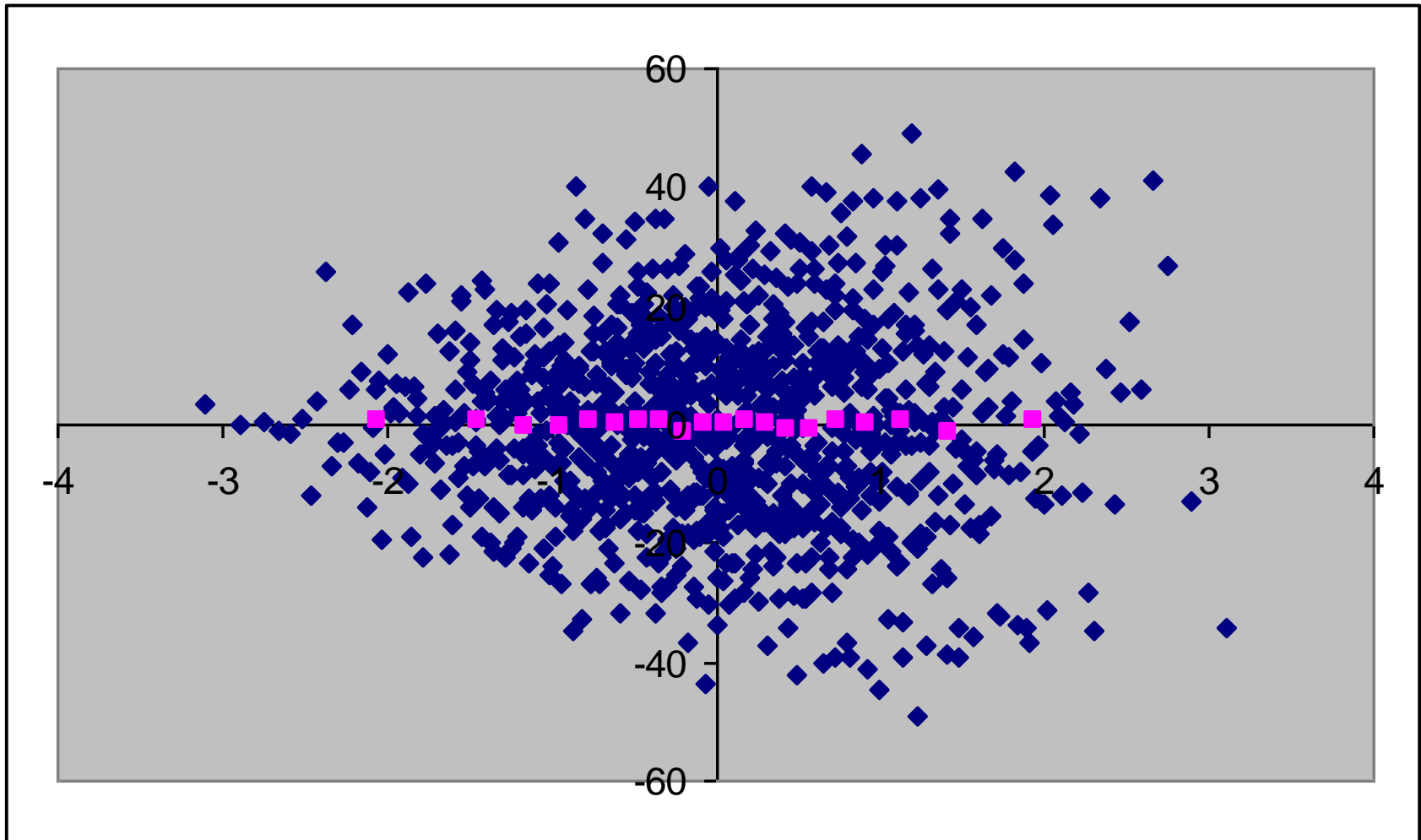
Issues of sampling (use of quasi-  
random numbers) ...

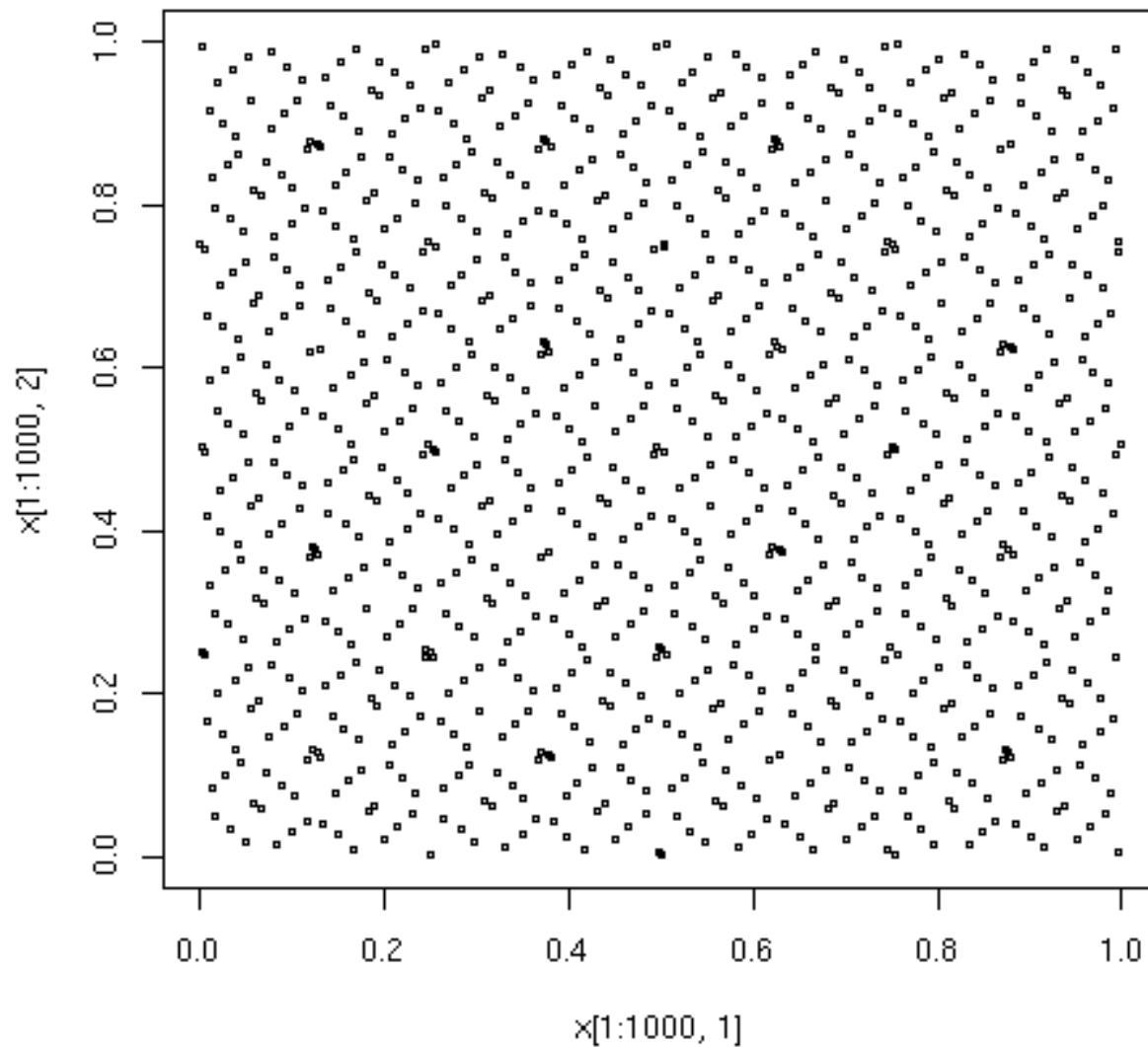


Which factor is more important?

Why?

Is this factor non-important?





An  $LP_\tau$  sequence

# Secrets of sensitivity analysis



First secret: The most important question is the question.

Corollary 1: Sensitivity analysis is not “run” on a model but on a model once applied to a question.

First secret: The most important question is the question.

Corollary 2: The best setting for a sensitivity analysis is one when one wants to prove that a question cannot be answered given the model

It is better to be in a setting of falsification than in one of confirmation (Oreskes et al., 1994 ).

[Normally the opposite is the case]

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/model which can be treated meaningfully.

[Often the love for the model prevails]

Badly kept secret:

There is always one more bug!

(Lubarsky's Law of Cybernetic  
Entomology)

And of course please don't ...

... run a sensitivity analysis where each  
factors has a 5% uncertainty



Why not?



# END

Twitter:  
[@andreasaltelli](https://twitter.com/andreasaltelli)