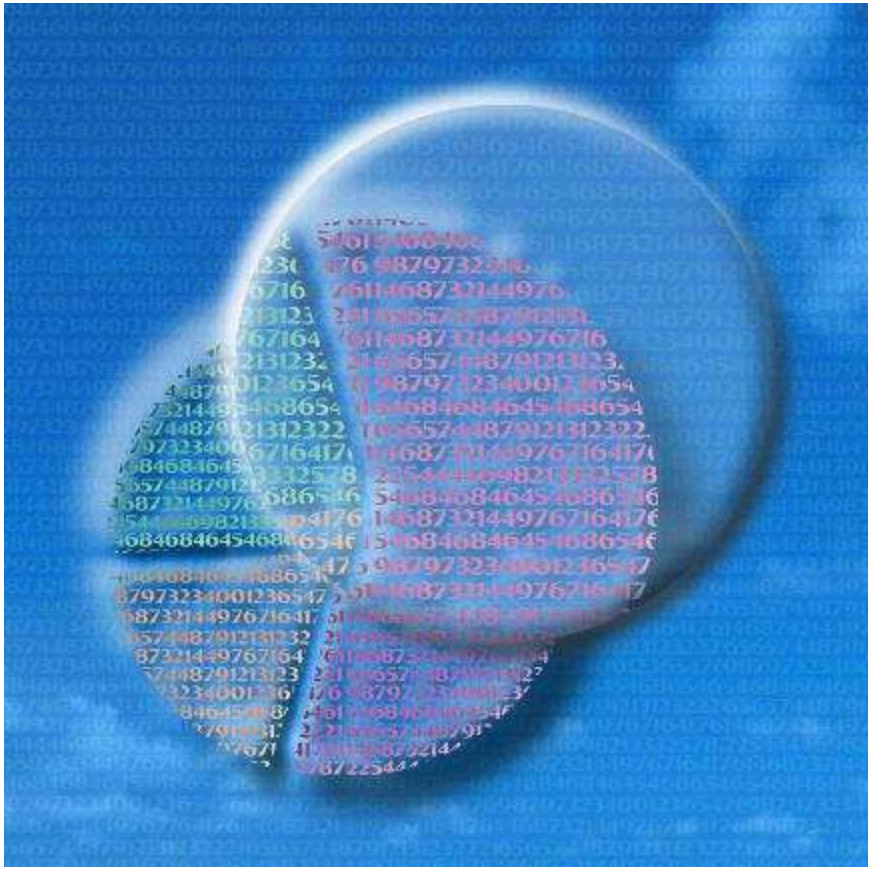


Quantification

Andrea Saltelli

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

Institut de Ciència i Tecnologia Ambientals (ICTA) – Universitat Autonoma de Barcelona (UAB)

Lesson for the Universities of York (Toronto), Vermont and McGill (Montreal)

andrea.saltelli@uib.no

Where to find this talk: www.andreasaltelli.eu

sensitivity analysis, sensitivity auditing, science for policy, impact assessment

= more material on my web site

= more material on Wikipedia

= discussion point

Problems and causes

Prologue

Science: is there a crisis?

Why Quantify? Quantification and trust

Evidence based policy and its opposite

Evidence as the currency of the lobbies

Economics and its cyclic crises of relevance
(the mathiness discussion)

Remedies and ways

Post-normal science

NUSAP

Sensitivity analysis

Sensitivity auditing

Quantitative story telling against hypocognition & Socially constructed ignorance

Prologue

"What follows is a hypothetical executive summary from an imagined Food and Agriculture Organization (FAO) report on the state of the world's food systems, written from the perspective of the 2050s"

Executive Summary: FAO State of World Agriculture in 2050 Draft Report

"[…]this FAO report presents evidence that the international food system of the second half of the 21st century is more sustainable than the food system of the late 20th or early 21st centuries.

[…] today more people are being fed on less land and agriculture is requiring fewer inputs.

[…] despite there being 10 billion people on the planet, today agriculture requires 438 million hectares* less land than it did in 2015, yet produces more adequate nutrition for all."

Executive Summary: FAO State of World Agriculture in 2050 Draft Report

Three digits

"[…] despite there being 10 billion people on the planet, today agriculture requires 438 million hectares* less land than it did in 2015, yet produces more adequate nutrition for all."

Authors' estimate

This [438 Mha] figure was arrived at by assuming that:

- Agriculture shifts away from over production of cereals, oils, and sugars, but increases fruit and vegetables;
- Agricultural yields increase ~1%/y between now and 2050.
- Protein consumption shifts from 86% animals and 14% plants to 50% animal and 50% plant.

Please contact the authors for references etc. pertaining to these calculations

The Washington Post

Speaking of Science

107 Nobel laureates sign letter blasting Greenpeace over GMOs

By Joel Achenbach

While Greenpeace and other organizations oppose genetically engineered food, more than 100 Nobel laureates are taking a stand on the side of GMOs. Here's a look at each side's arguments. (Jenny Starrs/The Washington Post)

"While Greenpeace and other organizations oppose genetically engineered food, more than 100 Nobel laureates are taking a stand on the side of GMOs. Here's a look at each side's arguments. (Jenny Starrs/The Washington Post)"

https://www.washingtonpost.com/news/speaking-of-science/wp/2016/06/29/more-than-100-nobel-laureates-take-on-greenpeace-over-gmo-stance/

From the Noble laureates' letter:

"Greenpeace has spearheaded opposition to Golden Rice, which has the potential to reduce or eliminate much of the death and disease caused by a vitamin A deficiency (VAD), which has the greatest impact on the poorest people in Africa and Southeast Asia.

[…] a total of one to two million preventable deaths occur annually as a result of VAD, […] VAD itself is the leading cause of childhood blindness globally affecting 250,000 – 500,000 children each year. Half die within 12 months of losing their eyesight.

[…] Opposition based on emotion and dogma contradicted by data must be stopped.

How many poor people in the world must die before we consider this a "**crime against humanity**"?"

http://supportprecisionagriculture.org/nobel-laureate-gmo-letter_rjr.html

Opposing evidence

Nutritionally: not enough beta carotene

Golden rice not commercialized yet

More politically viable alternative successful

Dangerous colour

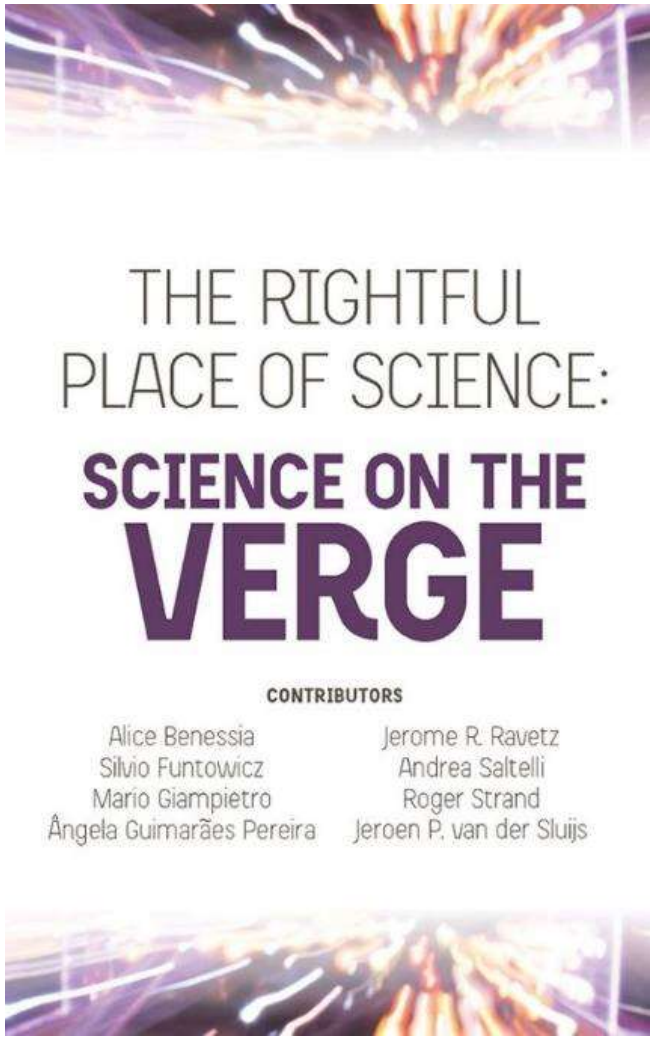
Low yield of the modified variety …

Source: Tiziano Gomiero, Andrea Saltelli and Mario Giampietro, The complexity of science for policy: the case of the delayed commercialization of the Golden Rice, Submitted October 2016.

References: Ye, X. et al., Science 287, 303 (2000); Paine, J.A. et al. Nature Biotechnology 23, 482 (2005); Datta, K. et al., Plant Biotechnol. J. 1, 81 (2003); IRRI http://irri.org/golden-rice/faqs/golden-rice-proven-to-reduce-vitamin-a-deficiency-and-its-health-consequences-like-blindness (accessed 2 August 2016); Nestle, M. J. Am. Diet. Assoc. 101, 289 (2001); WHO. http://www.who.int/nutrition/topics/vad/en/ (accessed 4 August 2016); IAPB. http://www.iapb.org/vision-2020/what-is-avoidable-blindness/vitamin-A (accessed 4 August 2016); FAO. http://www.fao.org/docrep/016/i3004e/i3004e.pdf (accessed 4 August 2016); Grenier, T. Solutions 5, 93 (2014); Stone, G.D., Glover, D. Agric. Hum. Values DOI 10.1007/s10460-016-9696-1 (2016); 15. Thurnham, D.I. Sight and life 26, 56 (2012); IRRI. http://irri.org/golden-rice/faqs/what-is-the-status-of-the-golden-rice-project-coordinated-by-irri (accessed 4 August 2016); Eisenstein, M. Nature 514, 55 (2014).

Is there a crisis?

Sources 1:



The Rightful Place of Science: Science on the Verge

Paperback – 20 Feb 2016

by Andrea Saltelli (Author), Alice Benessia (Author), & 7 more

1 customer review

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A crisis looms over the scientific enterprise. Not a day passes without news of retractions, failed replications, fraudulent peer reviews, or misinformed science-based policies.

Every day? http://www.nature.com/news/macchiarini-scandal-is-a-valuable-lesson-for-the-karolinska-institute-1.20539

Sources 2:

THE CONVERSATION

Academic rigour, journalistic flair

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Science in crisis: from the sugar scam to Brexit, our faith in experts is fading

September 27, 2016 4.43pm AEST

https://theconversation.com/science-in-crisis-from-the-sugar-scam-to-brexit-our-faith-in-experts-is-fading-65016

Unreliable research

Trouble at the lab

Scientists like to think of science as self-correcting. To an alarming degree, it is not

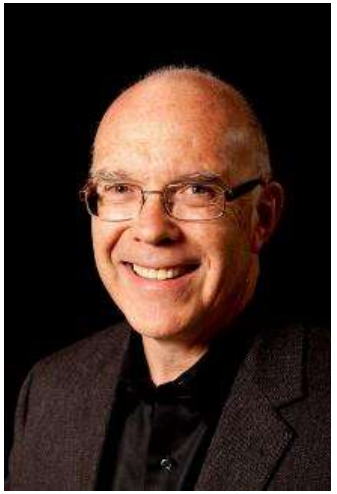
Oct 19th 2013 | From the print edition

The crisis has ethical, epistemological, methodological and even metaphysical dimensions;

Identified points of friction:

- paradigm of evidence-based policy
- use of science to produce implausibly precise numbers and reassuring techno-scientific imaginaries
- use of science to ‘compel’ decision by the sheer strength of ‘facts’

- Generation of new data/ publications at an unprecedented rate.
- Compelling evidence that the majority of these discoveries will not stand the test of time.
- Causes: failure to adhere to good scientific practice & the desperation to publish or perish.
- …



C. Glenn Begley

John P. A. Ioannides

NB: In the book we have a different theory but … read the book!

Begley, C. G., and Ioannidis, J. P., 2015, Reproducibility in Science. Improving the Standard for Basic and Preclinical Research, Circulation Research, 116, 116-126, doi: 10.1161/CIRCRESAHA.114.303819

Does the crisis impact science for policy & science's advice?

"Belinda Phipps, who took over at the Science Council last year, accused the sector of complacency and said the public trusted scientists only because they did not understand their work."

Whipple, T., The Times, February 22, 2016

THE TIMES

Science

News | Opinion | Business | Money | Sport | Life | Arts | Puzzles | Papers | Irish news

Welcome to your preview of The Times

Scientists 'should take ethics oath like doctors'

Tom Whipple Science Editor
Published at 12:01AM, February 22 2016

Scientists need their own version of the Hippocratic oath and a regulation system similar to doctors to avoid a big scandal, the head of their standards body has said.

Studies suggest that a significant proportion of scientific papers are not repeatable
Monty Rakusen/Corbis

Post a comment

"What struck me, coming into this sector is just how unregulated it is compared to the medical profession," Ms Phipps said. "Think what damage a scientist could do if he or she behaved badly or fraudulently. The potential damage is enormous, yet there is almost no regulation."

Whipple, T., The Times, February 22, 2016

THE TIMES

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Monty Rakusen/Corbis

Post a comment

Institutions charged with science advice choose to ignore the severity of the crisis

OECD publishing

Please cite this paper as:

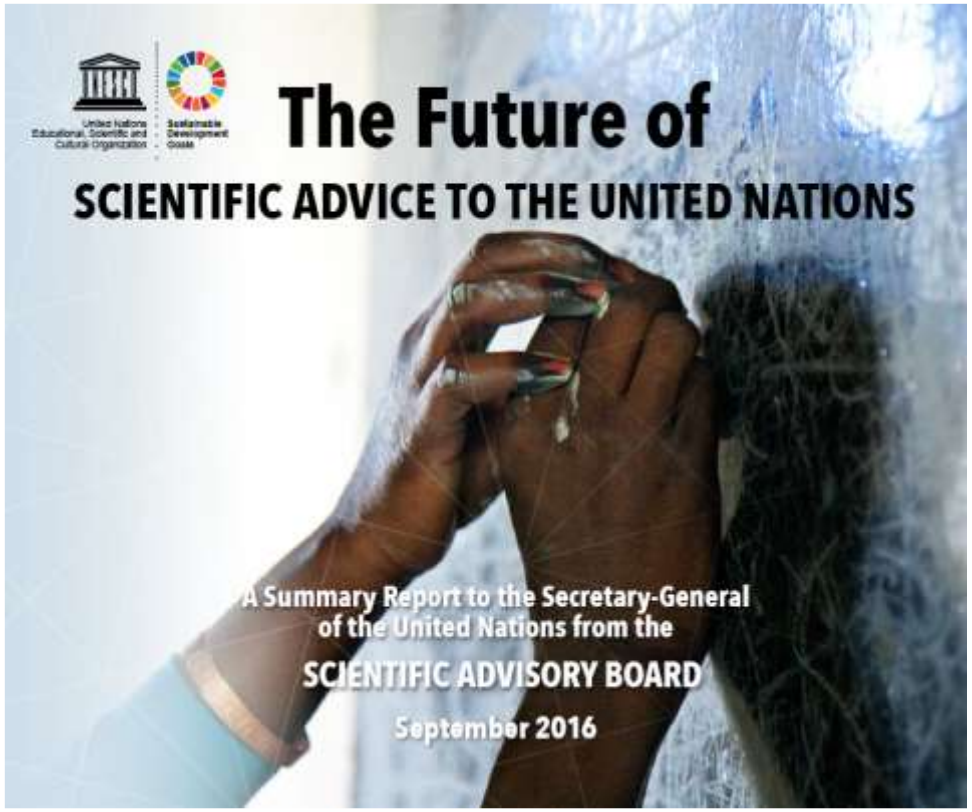
OECD (2015), "Scientific Advice for Policy Making: The Role and Responsibility of Expert Bodies and Individual Scientists", *OECD Science, Technology and Industry Policy Papers*, No. 21, OECD Publishing, Paris.
http://dx.doi.org/10.1787/5js33l1jcpwb-en

OECD Science, Technology and Industry Policy Papers No. 21

Scientific Advice for Policy Making

THE ROLE AND RESPONSIBILITY OF EXPERT BODIES AND INDIVIDUAL SCIENTISTS

OECD



Those aspect of science most used in policy (mathematical and statistical modelling) are also those more problematic. See e.g. the p-value saga…)

Saltelli, A., Funtowicz, S., 2014, 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/

Wasserstein, R.L. and Lazar, N.A., 2016. 'The ASA's statement on p-values: context, process, and purpose', The American Statistician, DOI:10.1080/00031305.2016.1154108.

Why quantify?

The myth of scientific quantification via risk or cost benefit analyses, including of the impact of new technologies, has been at the hearth of the critique of the ecological moment (e.g. Schumacher, 1973; Winner, 1986; Funtowicz and Ravetz, 1994)

E. F. Schumacher, 1973, Small Is Beautiful. Economics as if People Mattered, Penguin Perennial,

Winner, L., 1986. The Whale and the Reactor: a Search for Limits in an Age of High Technology. The University of Chicago Press, 1989 edition.

Funtowicz, S.O. and Ravetz, J.R. (1994). The worth of a songbird: Ecological economics as a post-normal science. Ecological Economics 10(3), 197-207.

[…] quality is much more difficult to 'handle' than quantity, just as the exercise of judgment is a higher function than the ability to count and calculate. Quantitative differences can be more easily grasped and certainly more easily defined than qualitative differences: their concreteness is beguiling and gives them the appearance of scientific precision, even when this precision has been purchased by the suppression of vital differences of quality.

Ernst Friedrich "Fritz" Schumacher

E. F. Schumacher, 1973, Small Is Beautiful. Economics as if People Mattered, Penguin Perennial,

Techniques (such as cost benefit analysis, CBA) are never neutral; according to Winner (1986) ecologists should not fall into the trap of CBA and risk analyses

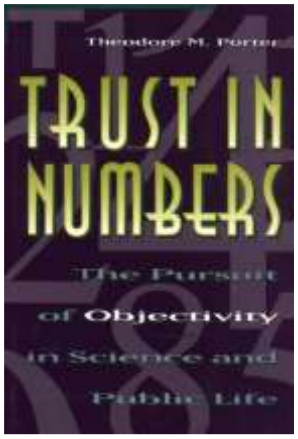
(Chapter ON NOT HITTING THE TAR-BABY)

Langdon Winner

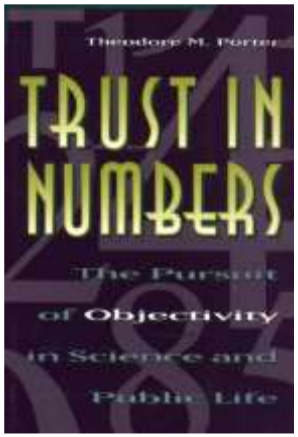
Winner, L., 1986. The Whale and the Reactor: a Search for Limits in an Age of High Technology. The University of Chicago Press, 1989 edition.

p. 8: “The appeal of numbers is especially compelling to bureaucratic officials who lack the mandate of a popular election, or divine right. Arbitrariness and bias are the most usual grounds upon which such officials are criticized. A decision made by the numbers (or by explicit rules of some other sort) has at least the appearance of being fair and impersonal.”

Theodor M. Porter



Theodore M. Porter, Trust in Numbers, The Pursuit of Objectivity in Science and Public Life, Princeton 1995



p. 8: “Scientific objectivity thus provides an answer to a moral demand for impartiality and fairness. Quantification is a way of making decisions without seeming to decide. Objectivity lends authority to officials who have very little of their own.”

Trust, authority and styles of quantification: two different stories

ECOLE NATIONALE
DES PONTS ET CHAUSSEES

US Army Corps of Engineers®

Porter's story: Quantification needs judgment which in turn needs trust …without trust quantification becomes mechanical, a system, and 'systems can be played'.

Discussion points

- Do I see a relationship between trust and quantification?
- Are we (my team, my organization) more like the ‘corps des ingénieurs des ponts et chaussées’ or the US Army corps of Engineers?
- Are we (my team, my organization) into evidence based policy or policy based evidence?

Evidence based policy or its opposite?

PETRUCHIO: I say it is the moon.

KATHERINE: I know it is the moon.

PETRUCHIO: Nay, then you lie. It is the blessèd sun.

KATHERINE: Then God be blessed, it is the blessèd sun.

But sun it is not, when you say it is not,

And the moon changes even as your mind.

...

(Shakespeare, the Taming of the Shrew, Act IV)

The expression ‘Policy based evidence’ has entered the public discourse.

Warring parties accuse one another of the sin.

“Greenpeace […] wants is policy based evidence making not evidence based policy making” (Sanderson, 2015) …

Wilkes, G., 2015, Free Lunch: Policy-based evidence-making, Financial Times, July 3.
Sanderson, A.B., 3 Feb 2015, Breitbart, see http://www.breitbart.com/london/2015/02/03/academic-attacks-greenpeace-for-ignoring-the-evidence-on-gm-crops/; the politician is UKIP Energy Spokesman Roger Helmer MEP.

“This need [for evidence] has been reified in the UK and elsewhere, as routines of 'evidence-based policy'-making have been hardwired into the business of Government.

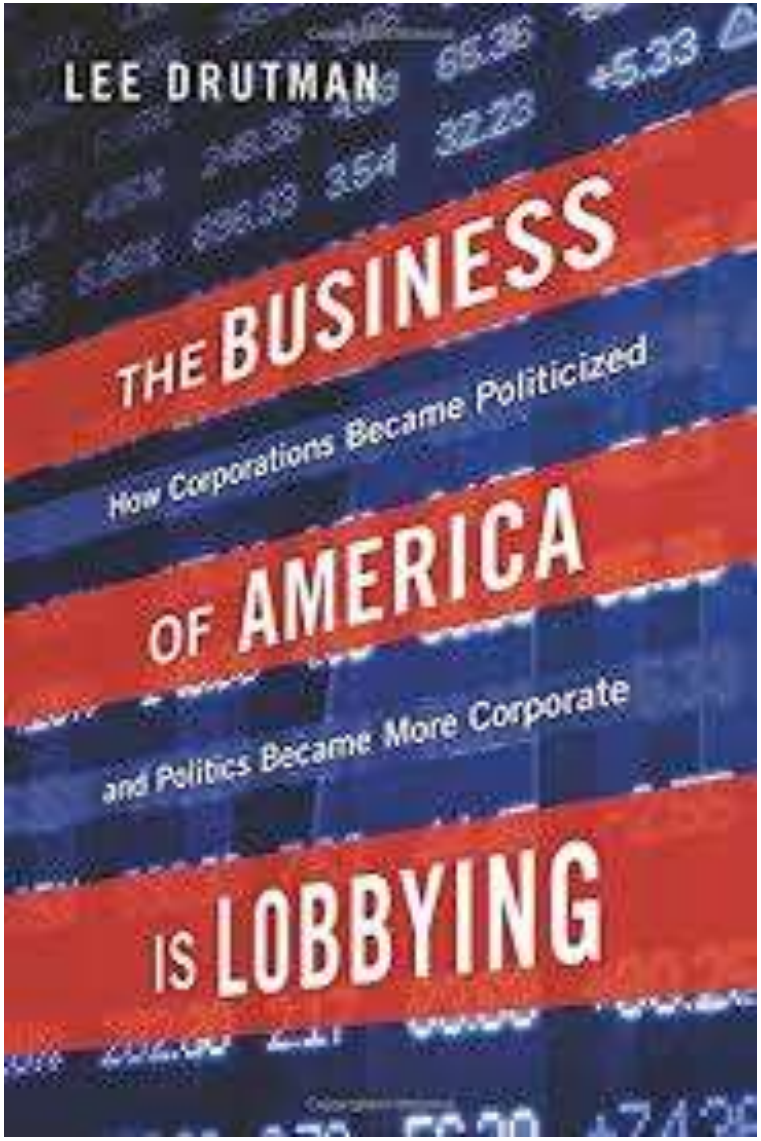
[…]such approaches are fundamentally flawed [because] Government […] seeks to capture and control the knowledge producing processes to the point where this type of 'research' might best be described as 'policy-based evidence'.”

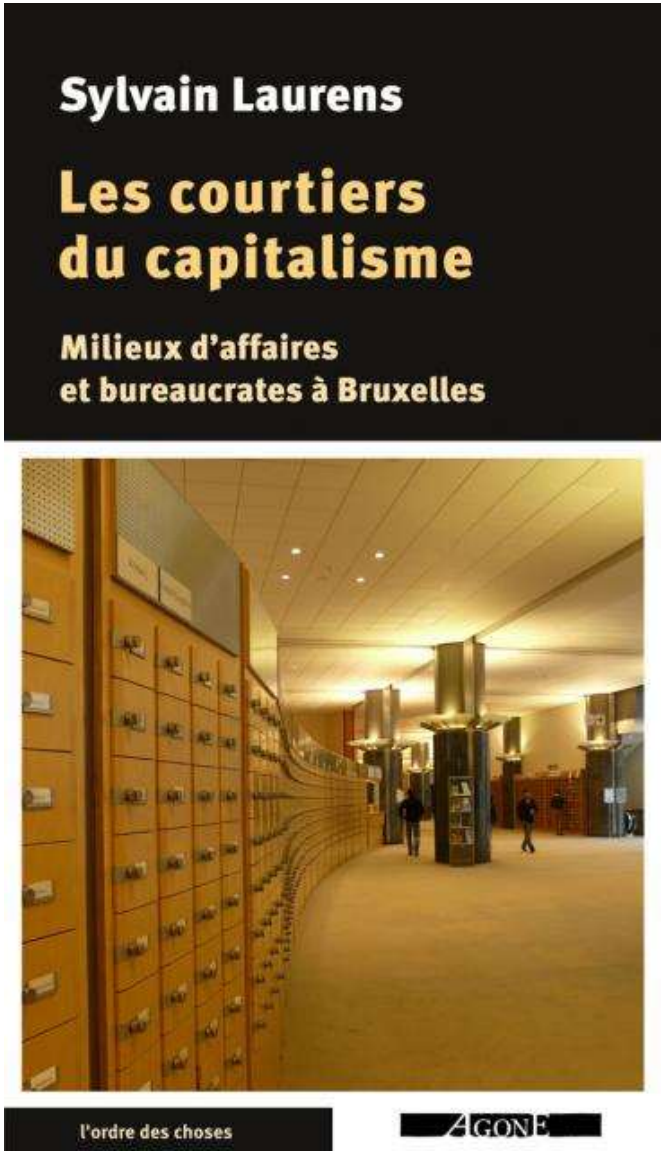
Boden, R. and Epstein D., 2006, Managing the Research Imagination? Globalisation and Research in Higher Education. *Globalisation, Societies and Education*, 223-236.

Discussion points

- Can I recall an example of ‘excessive’ or exaggerated quantification (hyper-precision)
- Am I haunted by a hidden assumptions, or by an elephants in the room nobody else sees?
- Can I recall an example of uncomfortable knowledge?

Evidence as the currency of lobbies





Lee Drutman

Sylvain Laurens

Some quick read:
http://www.nybooks.com/articles/2016/04/07/how-lobbyists-win-in-washington/
http://www.contretemps.eu/lectures/lire-extrait-courtiers-capitalisme-sylvain-laurens

général. Or, il existe une différence fondamentale entre avancer l'idée qu'un système démocratique serait simplement perverti par des lobbys et émettre l'hypothèse que l'existence de ces lobbys est consubstantielle d'un mode de gouvernement technocratique dans lequel la légitimité conférée à des élus par le suffrage universel ne pèse presque rien au regard d'autres critères. Ce

Sylvain Laurens, 2015, Les Courtiers du capitalisme, Milieux d'affaires et bureaucrates à Bruxelles, Marseille, Éditions Agone.

Economics and its cyclic crises of relevance

Today: the ‘Mathiness’ discussion: blogs of Paul Romer, Judith Curry and Erik Reinert’s ‘scholasticism’ paper.

See https://paulromer.net/mathiness/

https://judithcurry.com/2015/08/12/the-adversarial-method-versus-feynman-integrity-2/

http://www.andreasaltelli.eu/file/repository/Full_Circle_scholasticism_2.pdf

Paul Romer

Judith Curry

Erik Reinert

Post-normal science and NUSAP

What is Post-normal science?

STS scholars Silvio Funtowicz & Jerome R. Ravetz's

(STS=studies of science and technology)

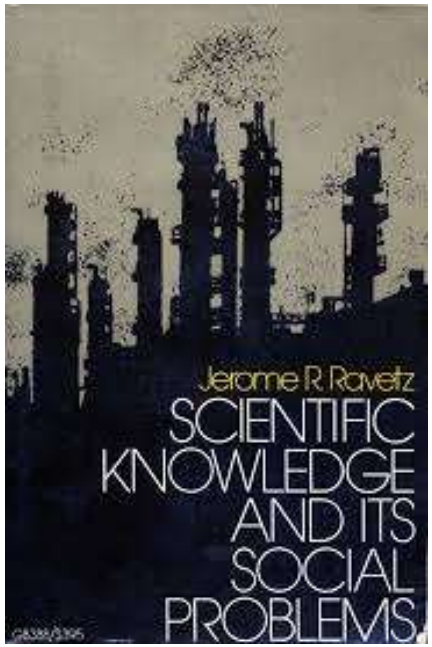
Funtowicz, S. O. and Ravetz, J. R., 1990. Uncertainty and quality in science for policy. Dordrecht: Kluwer.

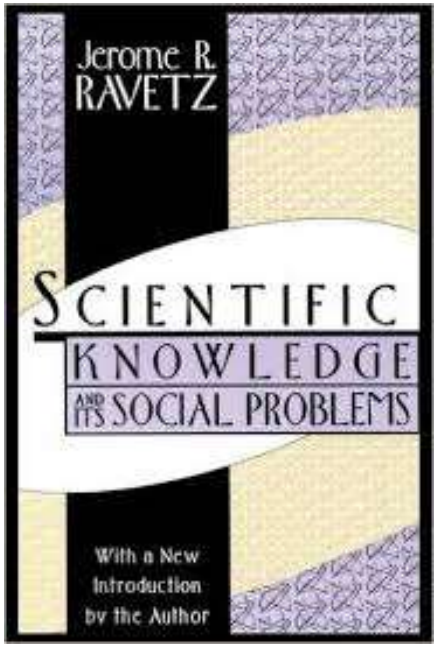
A book in 1971

A new critical science

From a science to domesticate nature to a science to remedy damages done by science and technology

The book includes a detailed prediction of the present problems of science quality system

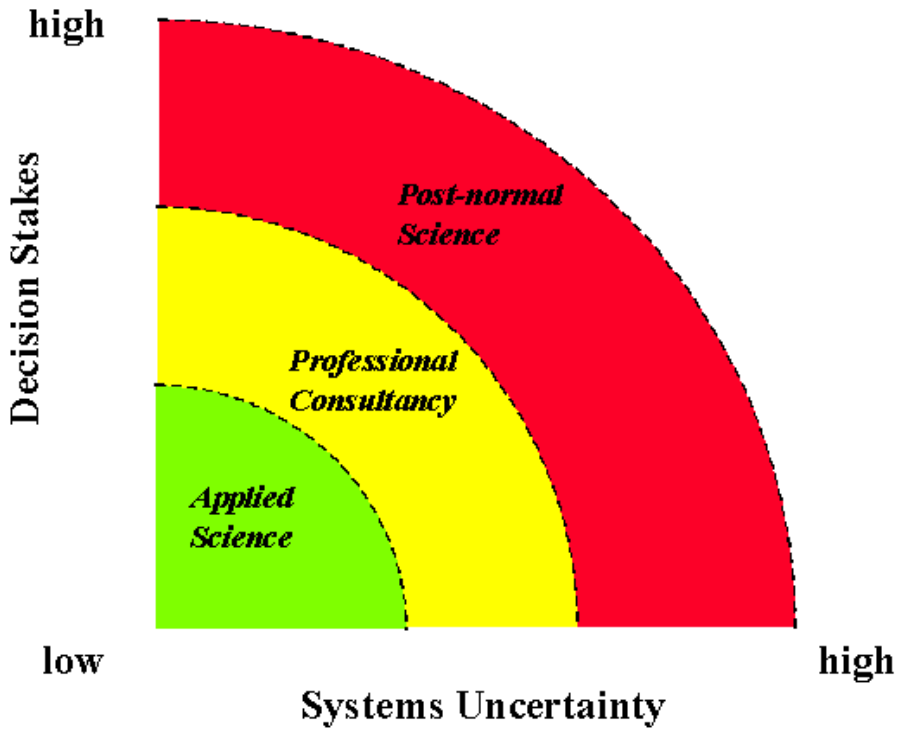




What is PNS? An empirical insights, not a doctrine

The **Mantra:**
Facts uncertain, stakes high, values in dispute, decisions urgent

Diagram, iconic; uncertainty (extending probability) and stakes (extending harm) not independent



Funtowicz, S. O. & Ravetz, J. R. 1993. Science for the post-normal age. Futures, 25(7), 739-755.

Post Normal Science's model of Extended Participation: (1) across disciplines – acknowledging that different disciplines see though different lenses, and (2) across communities of both experts and stakeholders; issues of fairness and quality.

The mission to truth replaced by the mission to quality

From 'speaking truth to power' towards 'working deliberatively within imperfections';

Funtowicz, S. O. & Ravetz, J. R. 1993. Science for the post-normal age. Futures, 25(7), 739–755.

- NUSAP, is a notational system for the management and communication of uncertainty in science for policy

Funtowicz, S. O. and Ravetz, J. R., 1990. Uncertainty and quality in science for policy. Dordrecht: Kluwer.

PNS toolbox

NUSAP is a notational system called for the management and communication of uncertainty in science for policy, based on five categories for characterizing any quantitative statement: Numeral, Unit, Spread, Assessment and Pedigree.

Jeroen van der Sluijs,

van der Sluijs, J., Craye, M., Funtowicz, S., Kloprogge, P., Ravetz, J., and Risbey, J. (2005) Combining Quantitative and Qualitative Measures of Uncertainty in Model based Environmental Assessment: the NUSAP System, Risk Analysis, 25 (2). p. 481-492.see also http://www.nusap.net/

Classic scientific notational system:
Numeral Unit Spread

For problems in the post-normal domain, add two qualifiers:
Assessment & Pedigree

- "Assessment" expresses expert judgement on reliability of numeral + spread
- "Pedigree" expresses multi-criteria evaluation of the strength of a number by looking at:
  - Background history by which the number was produced
  - Underpinning and scientific status of the number

Example Pedigree matrix parameter strength

Code	Proxy	Empirical	Theoretical basis	Method	Validation
4	Exact measure	Large sample direct mmts	Well established theory	Best available practice	Compared with indep. mmts of same variable
3	Good fit or measure	Small sample direct mmts	Accepted theory partial in nature	Reliable method commonly accepted	Compared with indep. mmts of closely related variable
2	Well correlated	Modeled/derived data	Partial theory limited consensus on reliability	Acceptable method limited consensus on reliability	Compared with mmts not independent
1	Weak correlation	Educated guesses / rule of thumb est	Preliminary theory	Preliminary methods unknown reliability	Weak / indirect validation
0	Not clearly related	Crude speculation	Crude speculation	No discernible rigour	No validation

EPILOGUE

"…Numbers, however, are still esoteric knowledge, the property of a small set of initiates […]
Only when there is effective quality control of science for policy, through the management of uncertainties, will we be able to cope intelligently with the crises we face.
The demystification of the mathematics of uncertainty is therefore a central part of the programme for the democratization of scientific expertise. This is our contribution."

Silvio O. Funtowicz & Jerome R. Ravetz, 1990. *Uncertainty and quality in science for policy*. Kluwer: Dordrecht. p. 209

Why sensitivity analysis

Definition of uncertainty and sensitivity analysis.

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

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

Why sensitivity analysis

Edward E. Leamer

<<I have proposed a form of organised sensitivity analysis that I call "global sensitivity analysis" in which a neighborhood of alternative assumptions is selected and the corresponding interval of inferences is identified.>>

Edward E. Leamer, 1990, Let's Take the Con Out of Econometrics, American Economics Review, 73 (March 1983), 31-43.

Edward E. Leamer

<<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.>>

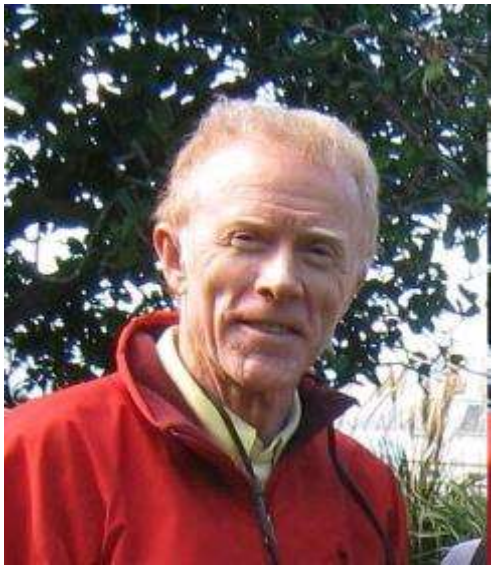
Edward E. Leamer, 1990, Let's Take the Con Out of Econometrics, American Economics Review, 73 (March 1983), 31-43.

Funtowicz & Ravetz's GIGO (Garbage In, Garbage Out) Science – or pseudo-science –

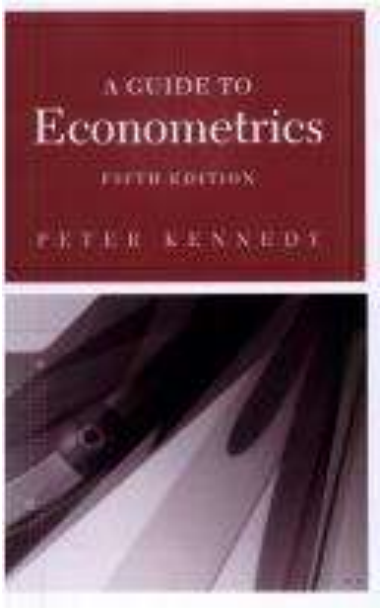
"where uncertainties in inputs must be suppressed least outputs become indeterminate"

Funtowicz, S. O. and Ravetz, J. R., 1990. Uncertainty and quality in science for policy. Dordrecht: Kluwer.

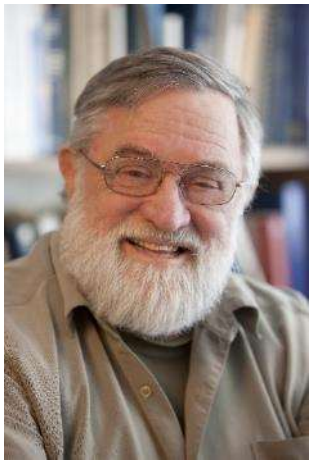
Peter Kennedy, A Guide to Econometrics.
Anticipating criticism by applying sensitivity analysis. This is one of the ten commandments of applied econometrics according to Peter Kennedy:



<<Thou shall confess in the presence of sensitivity.
Corollary: Thou shall anticipate criticism >>

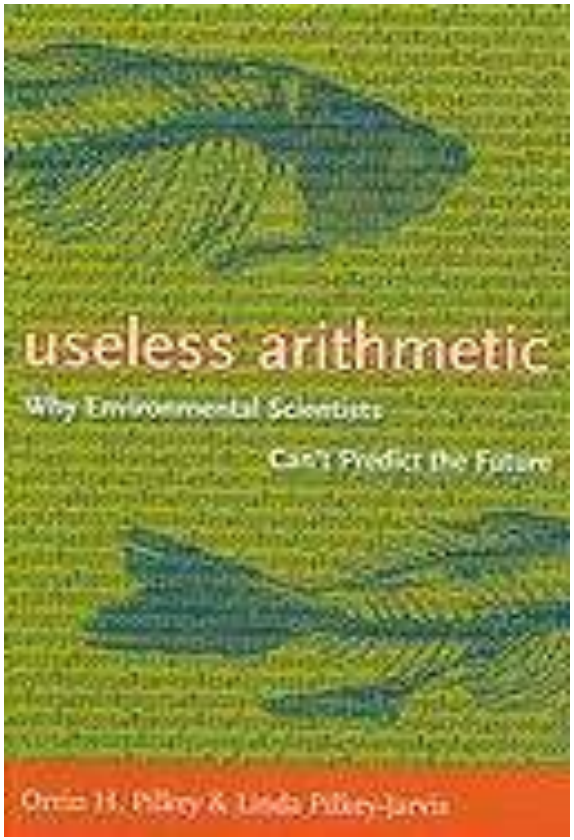


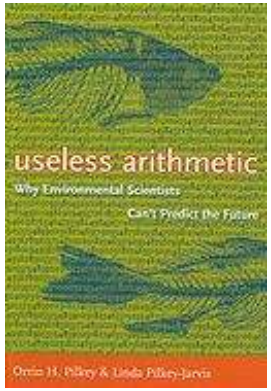
Limits of sensitivity analysis



Orrin H. Pilkey
Duke University, NC

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



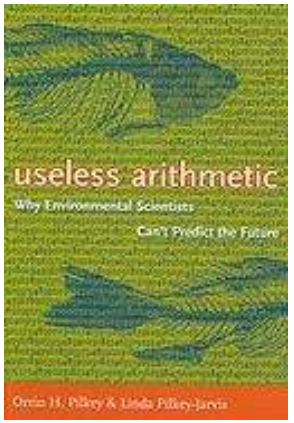


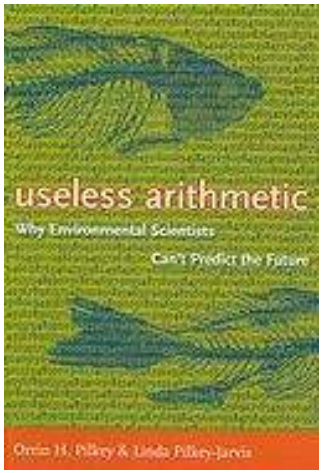
<<It is important, however, to recognize that the sensitivity of the parameter in the equation is what is being determined, not the sensitivity of the parameter in nature.

[…] 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.>>

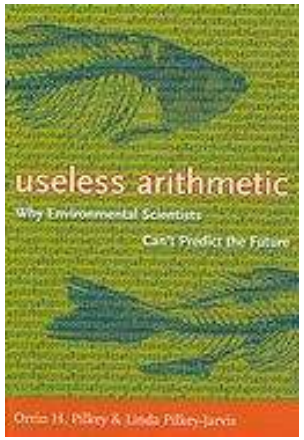
One of the examples discussed concerns the Yucca Mountain repository for radioactive waste. TSPA model (for total system performance assessment) for safety analysis.

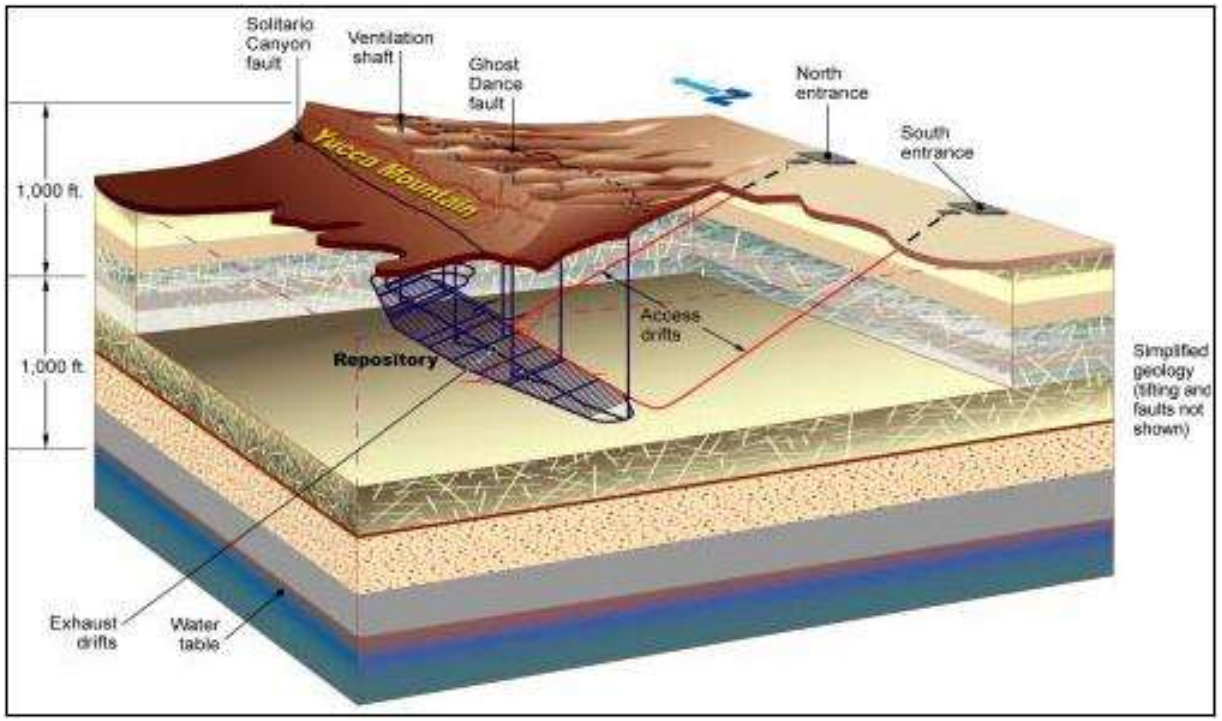
TSPA is Composed of 286 sub-models.





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.

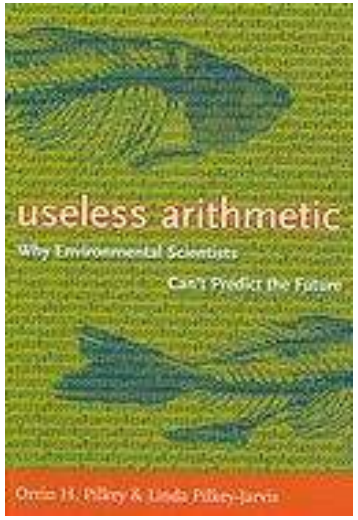




The confidence of the stakeholders in TSPA was not helped when evidence was produced which could lead to an upward revision of 4 orders of magnitude of this parameter
(the ^{36}Cl story)

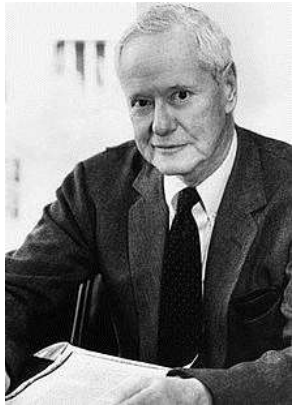
In the case of TSPA (Yucca mountain) a range of 0.02 to 1 millimetre per year was used for percolation of flux rate.

→… 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 '



Robert K. Merton

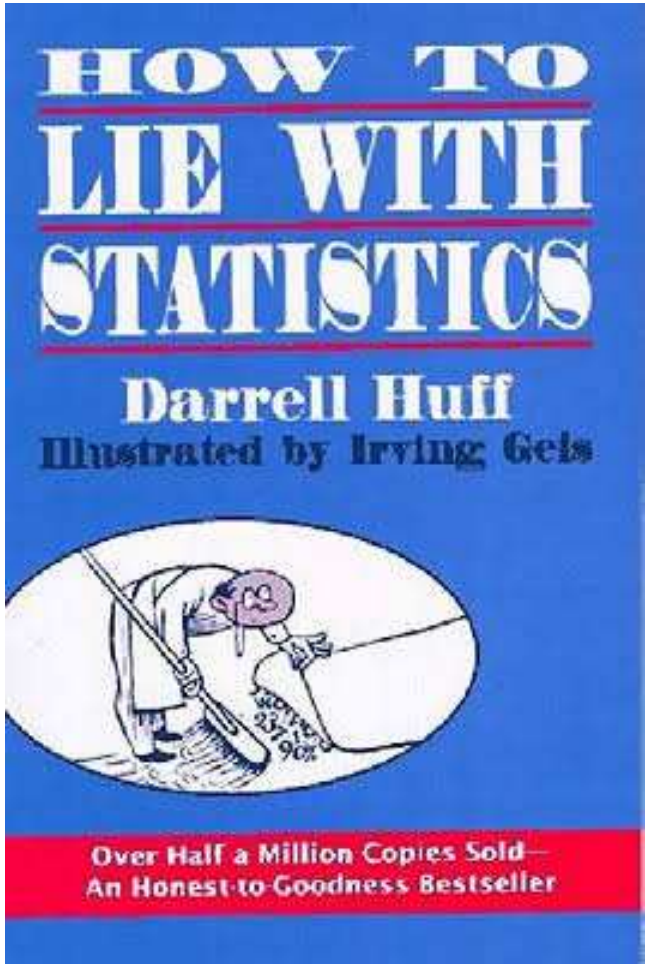
Communalism - the common ownership of scientific discoveries, according to which scientists give up intellectual property rights in exchange for recognition and esteem (Merton actually used the term Communism, but had this notion of communalism in mind, not Marxism);

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.

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



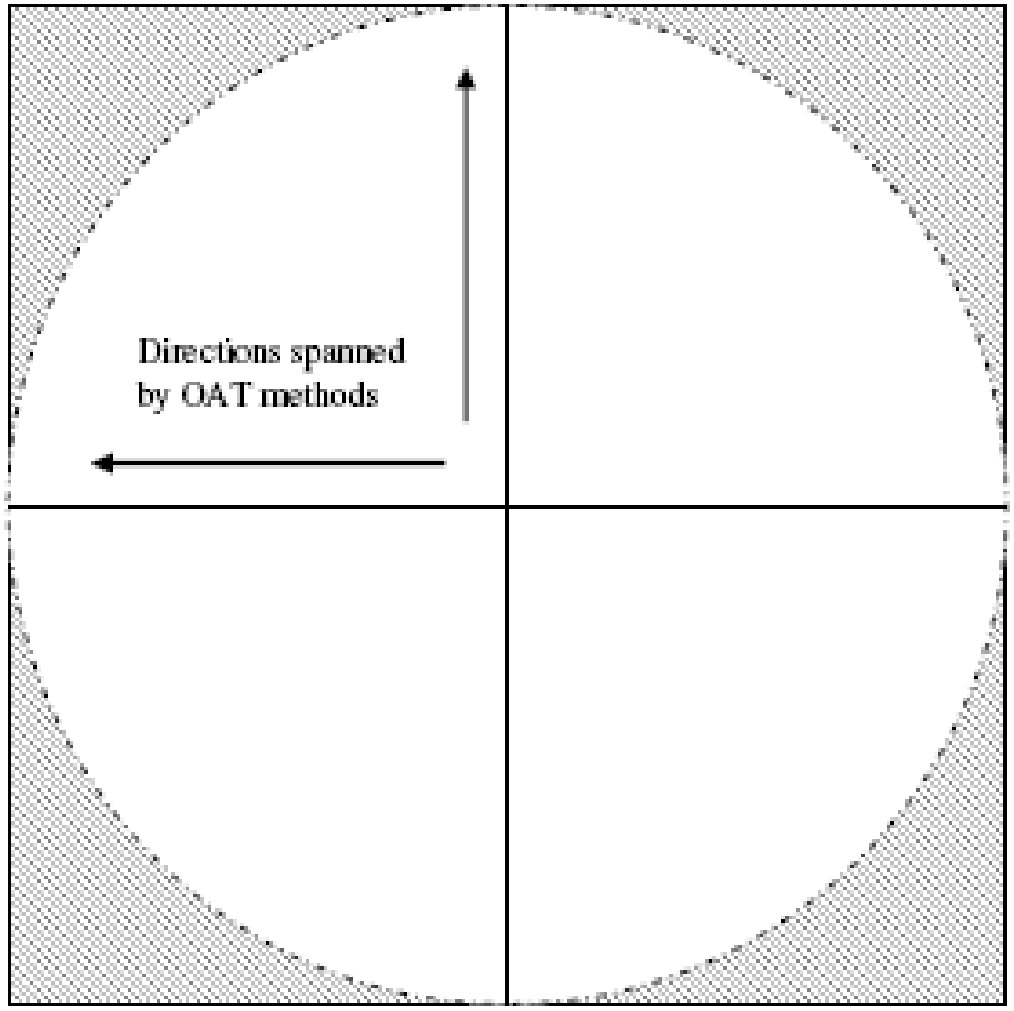
Saltelli, A., Annoni P., 2010, How to avoid a perfunctory sensitivity analysis, *Environmental Modeling and Software,* **25**, 1508-1517.

What do these have in common?

J. Campbell, *et al.*, *Science* **322**, 1085 (2008).
R. Bailis, M. Ezzati, D. Kammen, *Science* **308**, 98 (2005).
E. Stites, P. Trampont, Z. Ma, K. Ravichandran, *Science* **318**, 463 (2007).
J. Murphy, et al., *Nature* **430**, 768-772 (2004).
J. Coggan, *et al.*, *Science* **309**, 446 (2005).

They use a one factor at a time approach (OAT)

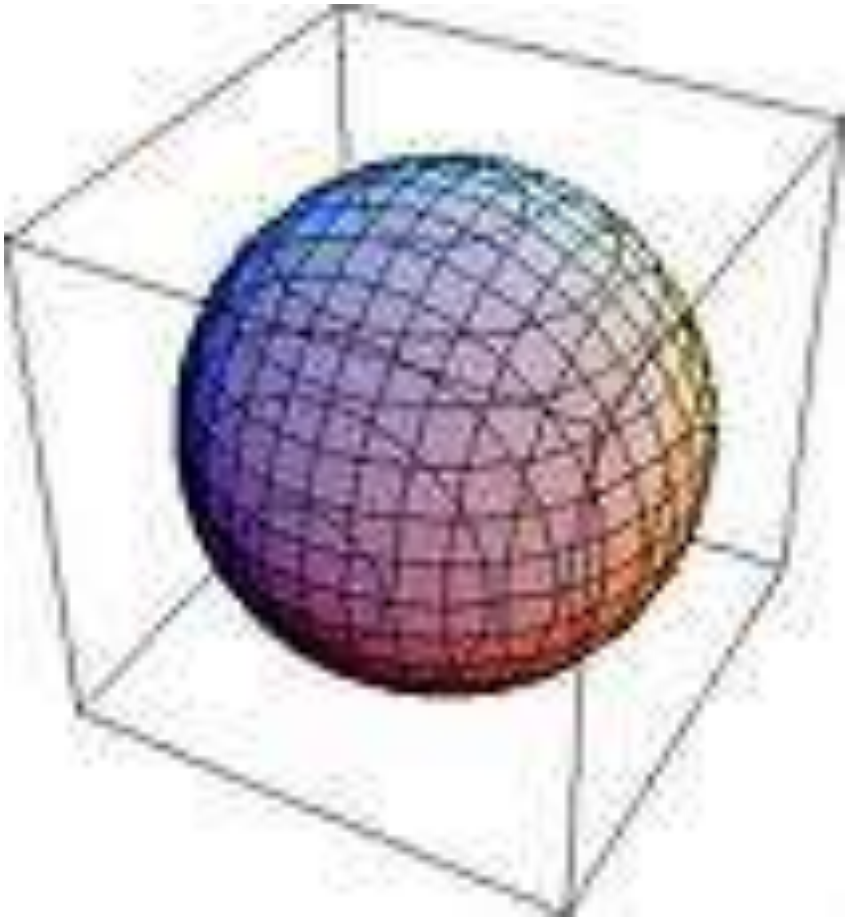
OAT in 2 dimensions



Area circle / area square =?

~ 3/4

OAT in 3 dimensions



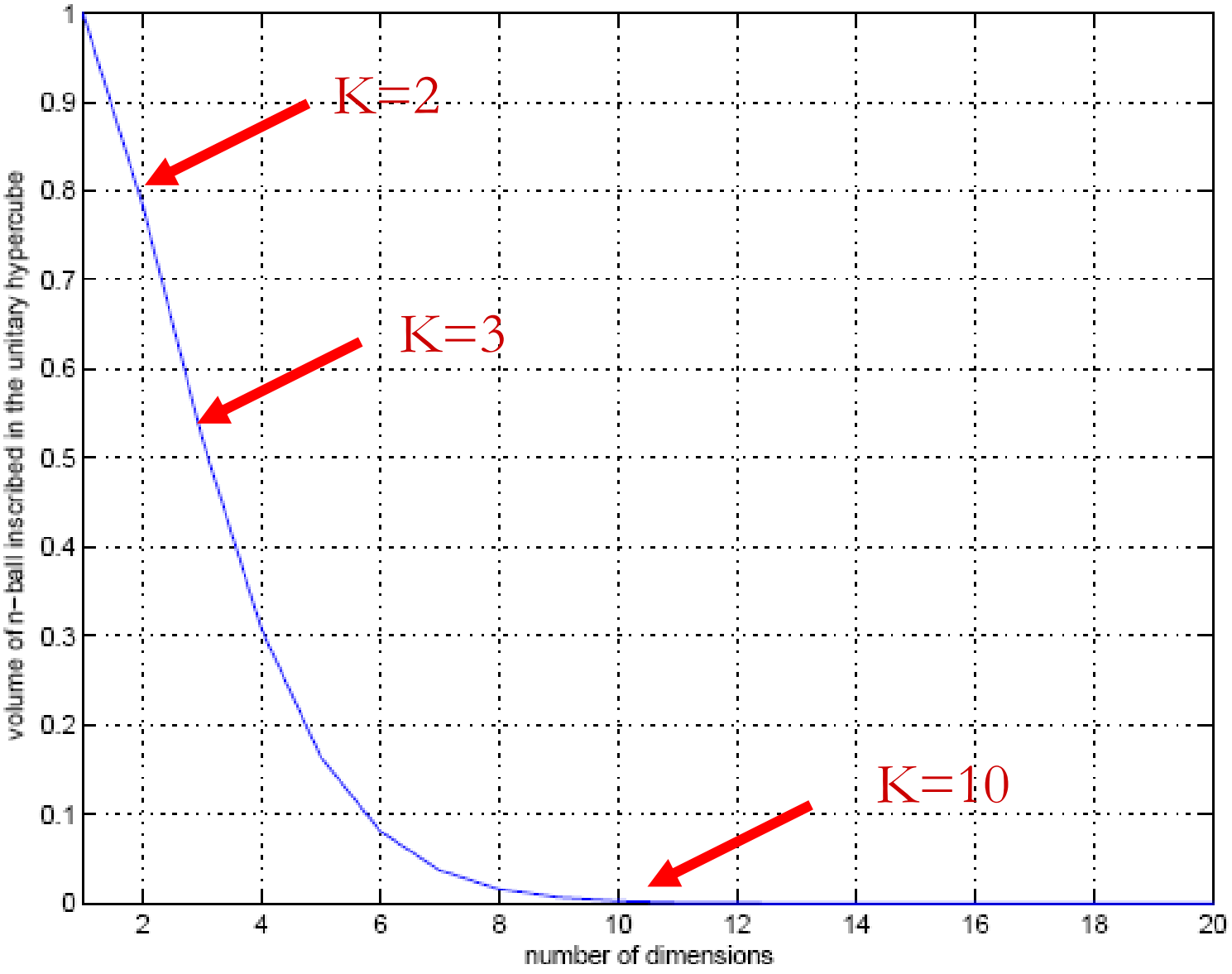
Volume sphere / volume cube =?

~ 1/2

OAT in 10 dimensions

Volume hypersphere / volume ten dimensional hypercube =? ~ 0.0025

OAT in k dimensions



[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"

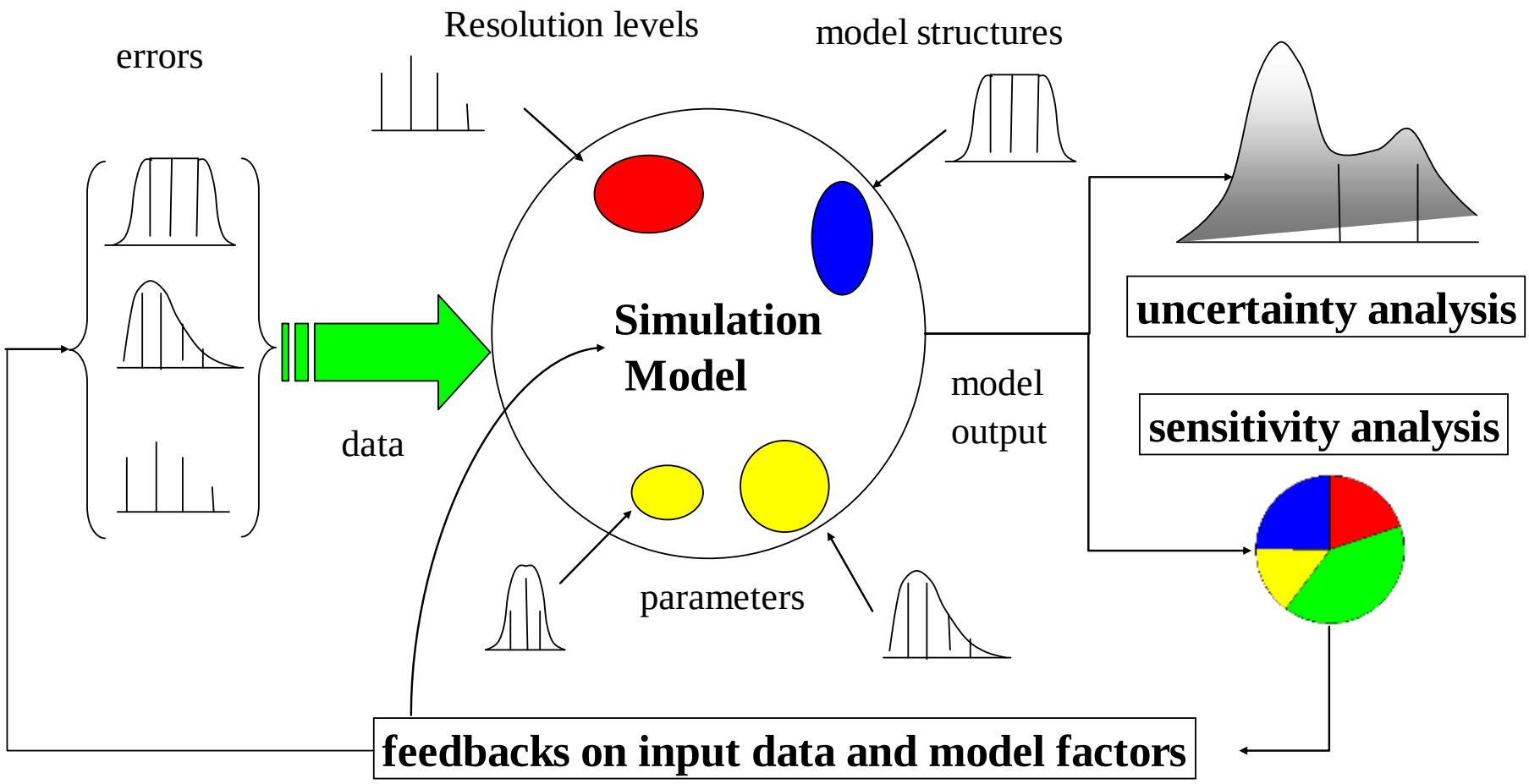
Saltelli A., 2002, Sensitivity Analysis for Importance Assessment, Risk Analysis, 22 (3), 1-12.

Suggested strategy for SA

- Modelling in a Monte Carlo framework

- All uncertainties activated simultaneously; uncertainty and sensitivity together

An engineer's vision of UA, SA

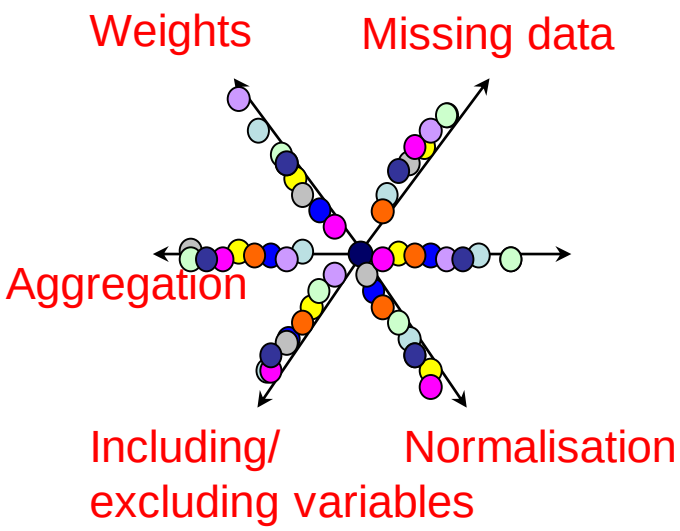


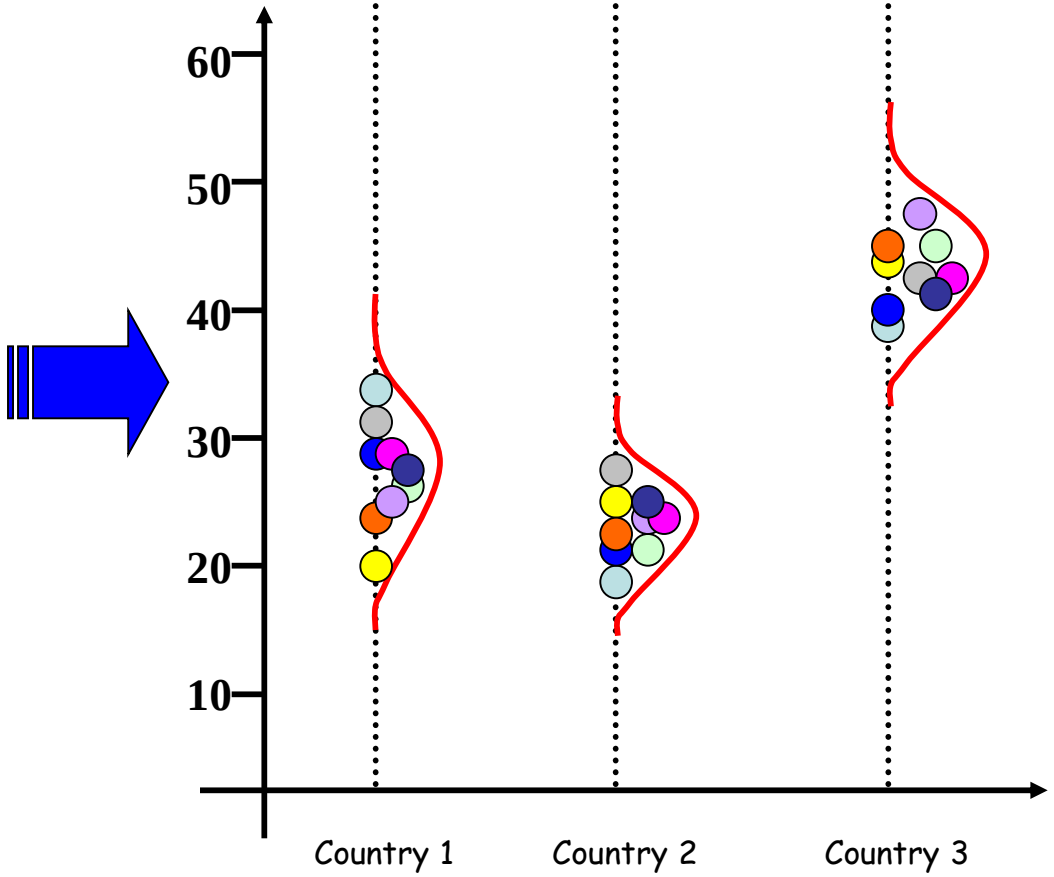
Tips

- One can sample more than just factors …
- Using triggers one can sample modelling assumptions; example: Y is a composite indicator

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

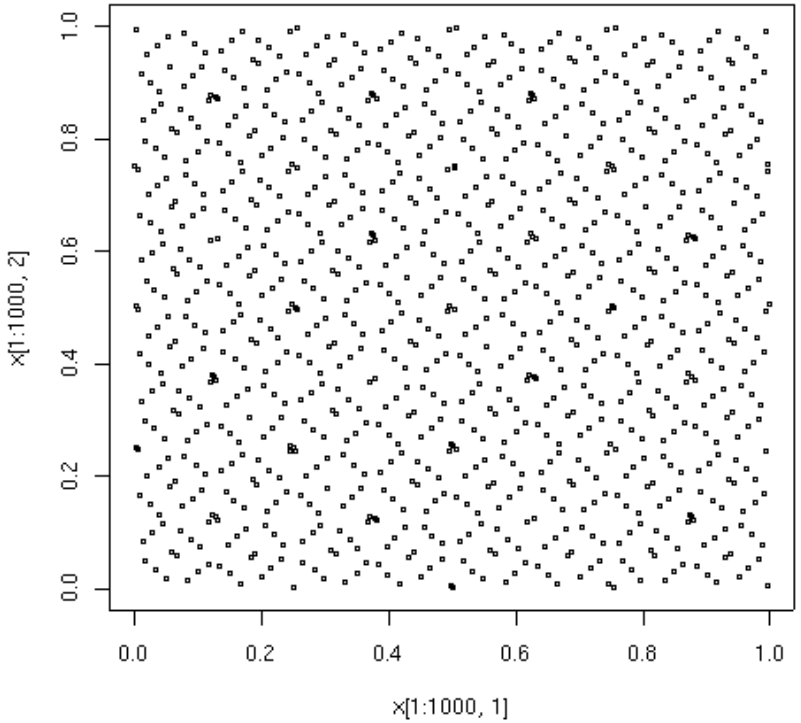
Space of alternatives





Tips

- Use quasi random numbers (LP_τ)



Ilya M. Sobol'

Sample matrix for parametric bootstrap.

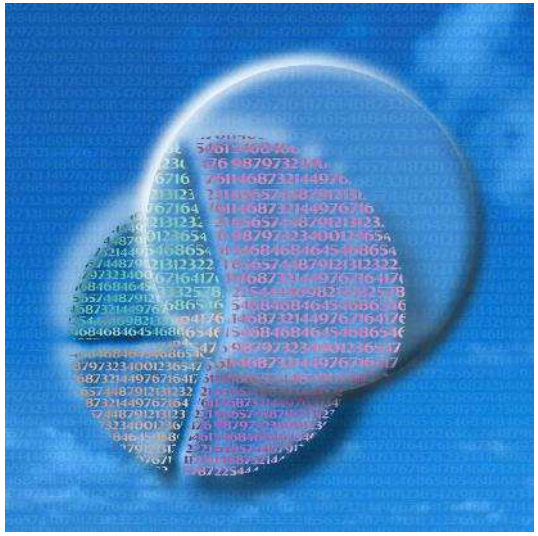
$$\begin{matrix} x_{11} & x_{12} & \dots & x_{1k} \\ x_{21} & x_{22} & \dots & x_{2k} \\ \dots & \dots & \dots & \dots \\ x_{N1} & x_{N2} & \dots & x_{Nk} \end{matrix}$$

Each row is a sample trial for one model run. Each column is a sample of size N from the marginal distribution of the parameters as generated by the estimation procedure.

Model results:

Each row is the error-free result of the model run.

$$y_1$$
$$y_2$$
$$\dots$$
$$y_N$$

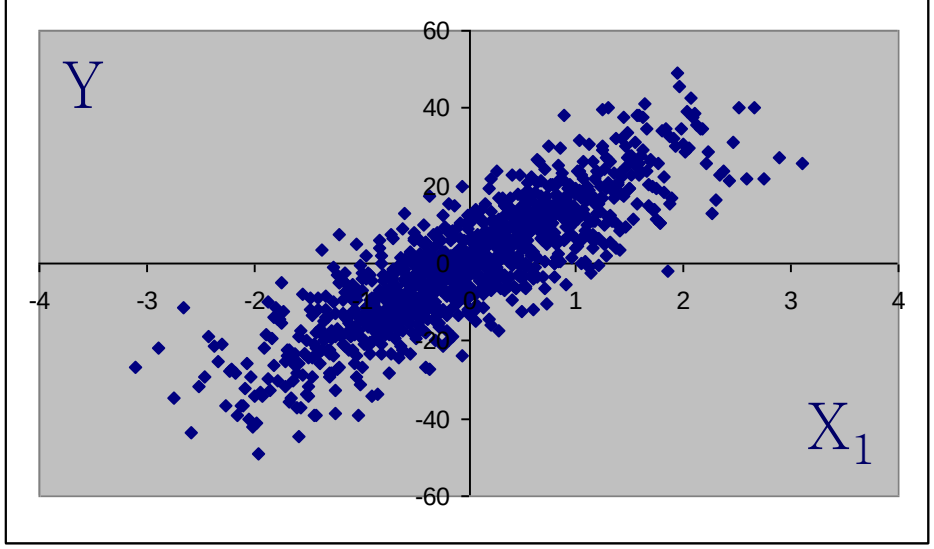


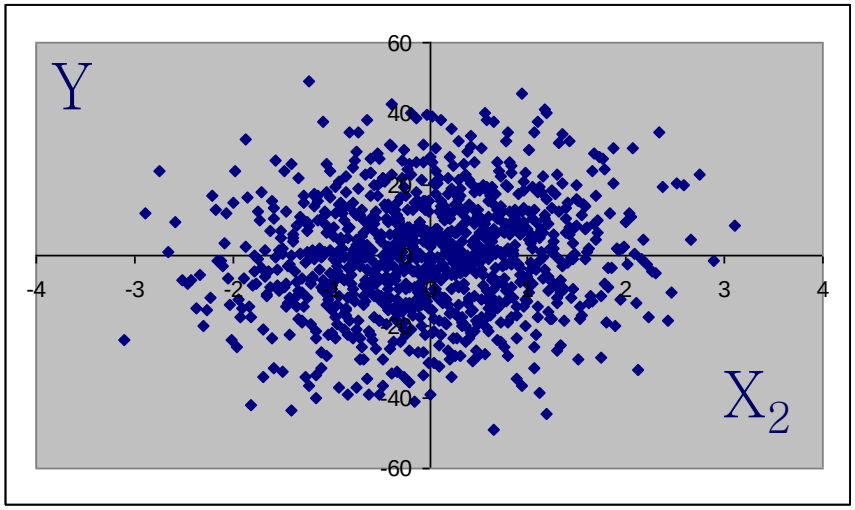
Our preferred methods for SA: variance based

An intuitive derivation of sensitivity indices

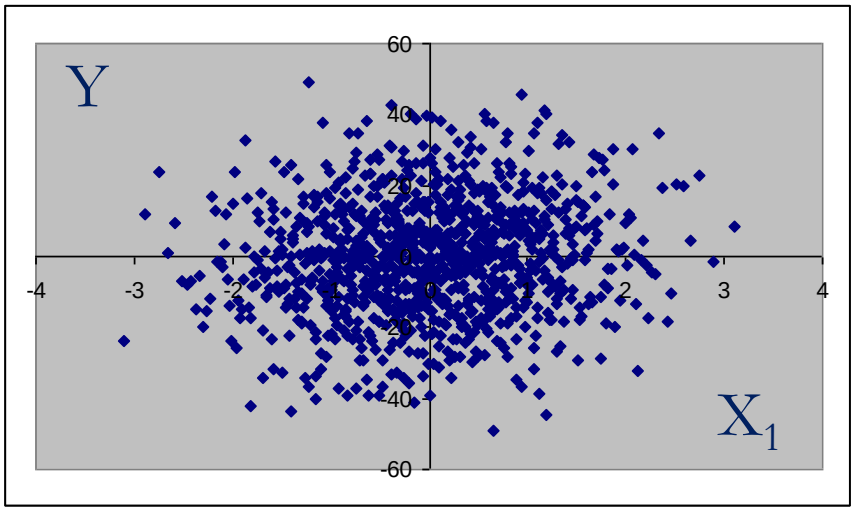
$$\begin{matrix} x_{11} & x_{12} & \dots & x_{1k} \\ x_{21} & x_{22} & \dots & x_{2k} \\ \dots & \dots & \dots & \dots \\ x_{N1} & x_{N2} & \dots & x_{Nk} \end{matrix}$$

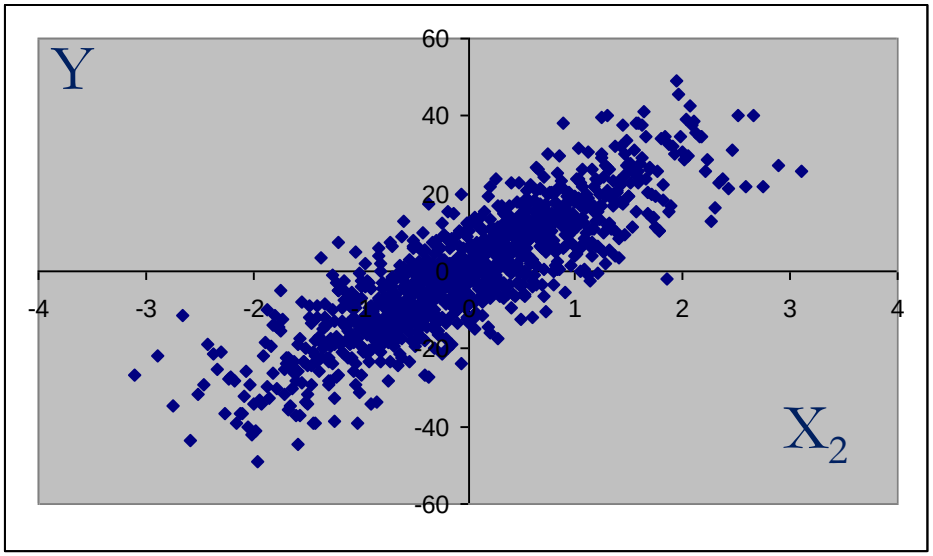
$$\begin{matrix} y_1 \\ y_2 \\ \dots \\ y_N \end{matrix}$$





Scatterplots of y versus sorted factors

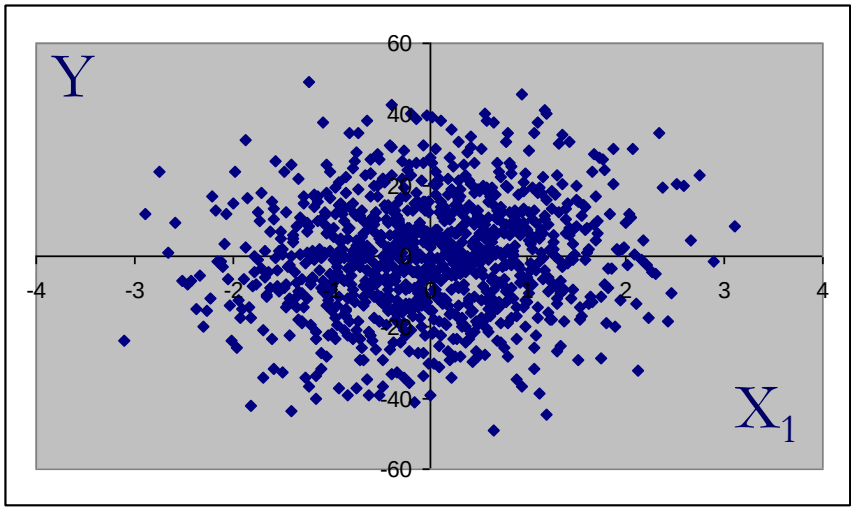


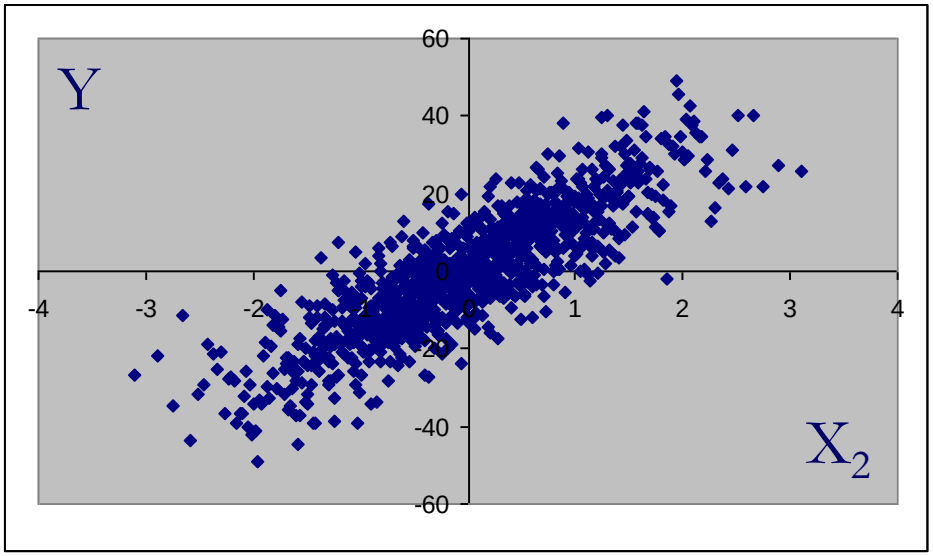


The ordinate axis is always Y

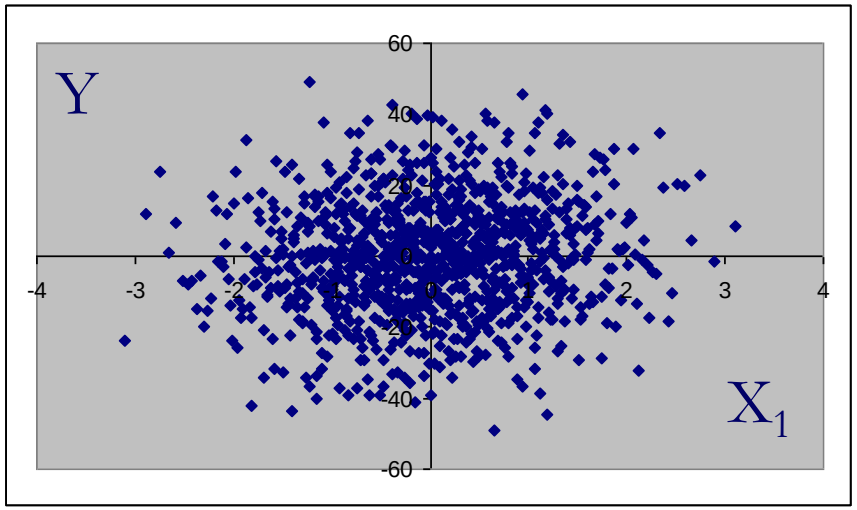
The abscissa are the various factors X_i in turn.

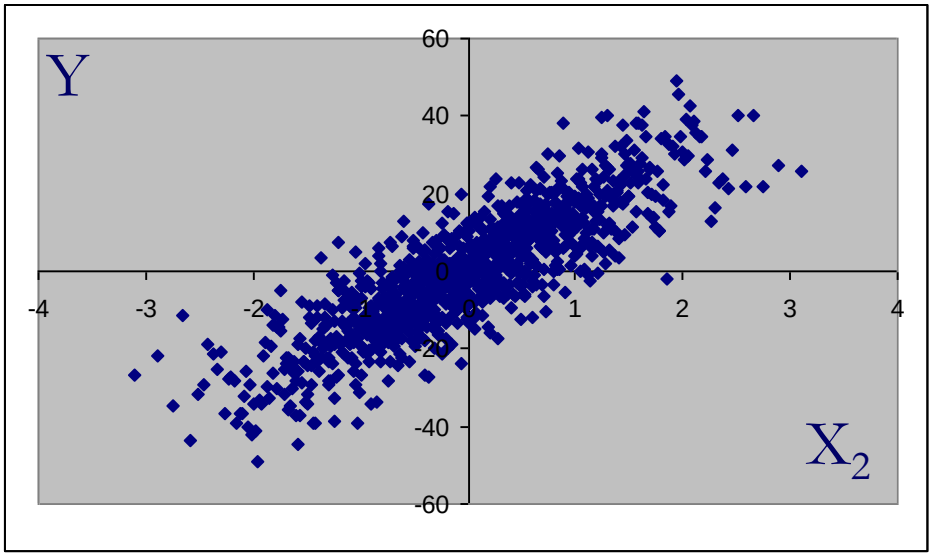
The points are always the same





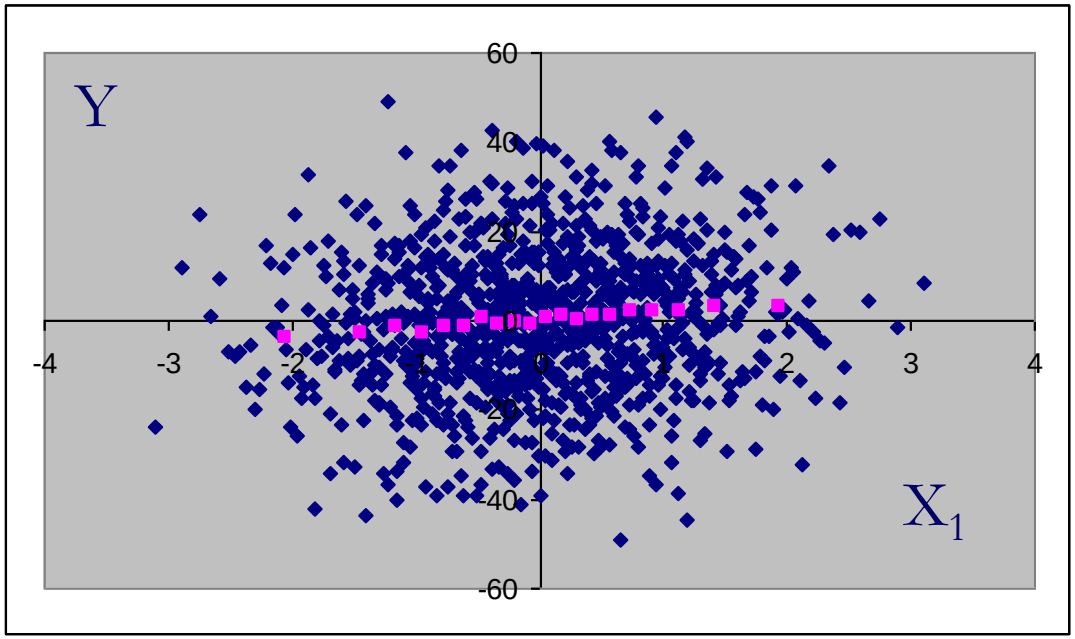
Which factor is more important?

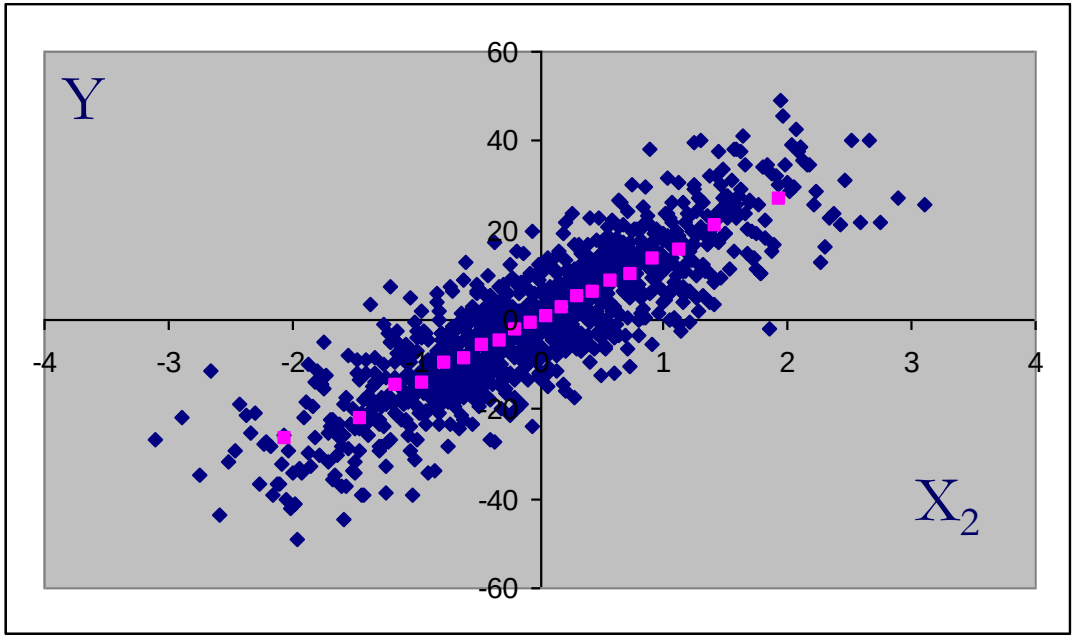




These are ~1,000 points

Divide them in 20 bins of ~ 50 points

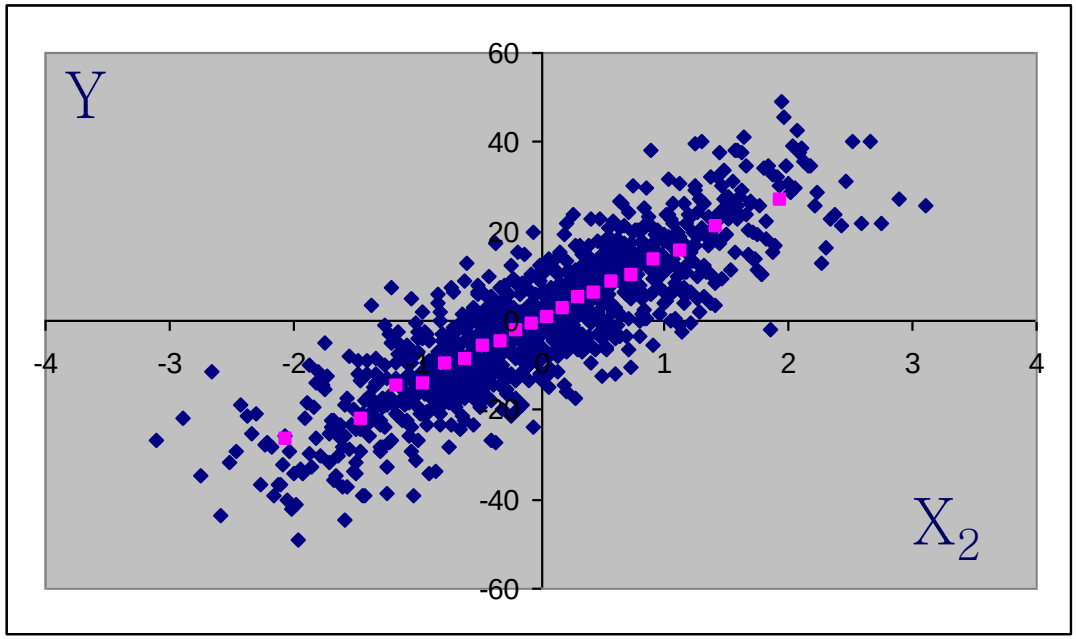




~1,000 blue points

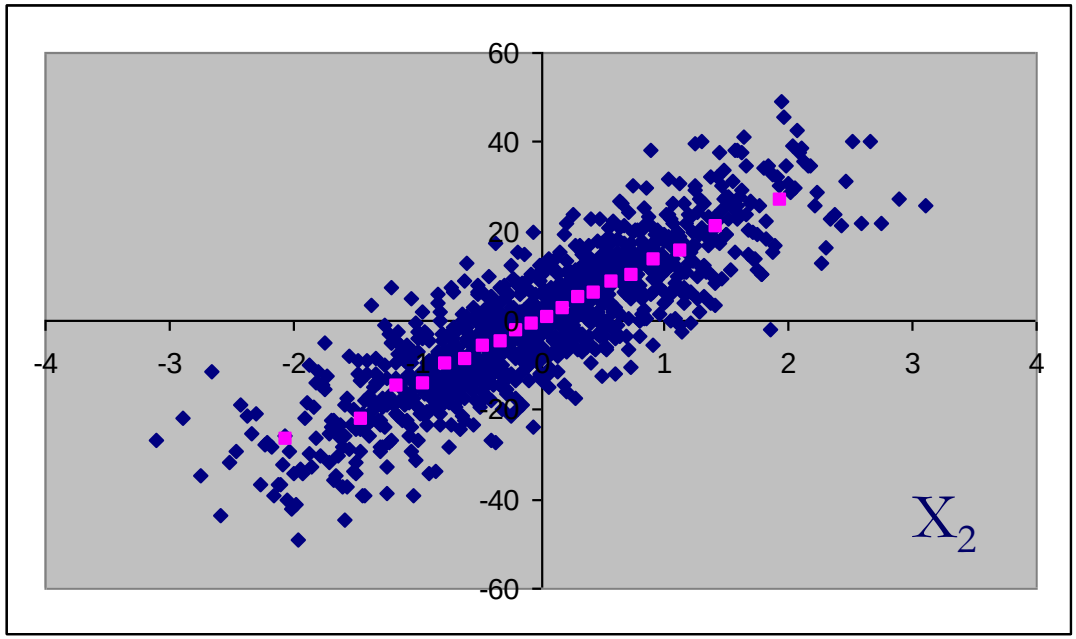
Divide them in 20 bins of ~ 50 points

Compute the bin's average (pink dots)



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

Y



Take the variance of the pinkies

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

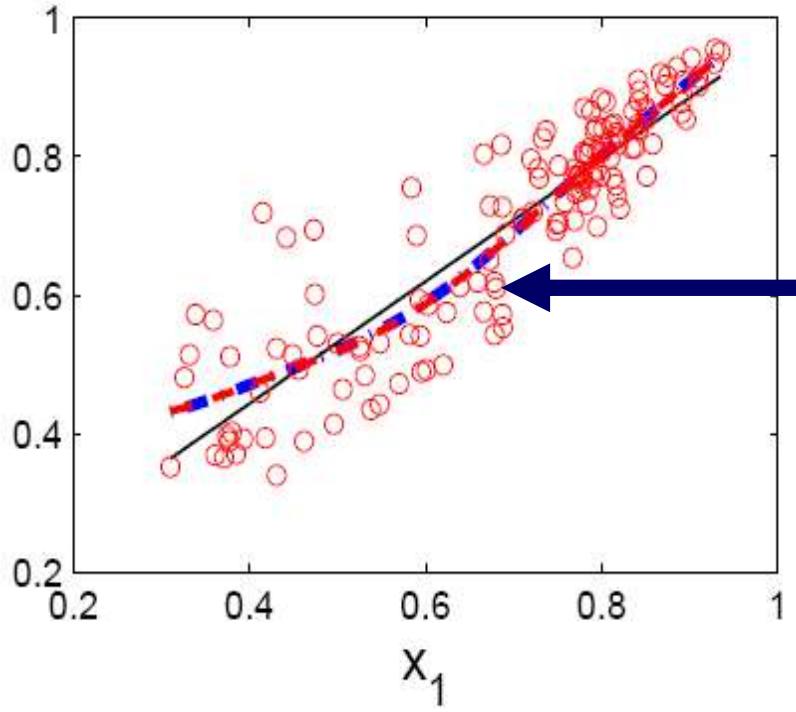
Pearson's correlation ratio

Smoothed curve

$$S_i \equiv \eta_i^2 := \frac{\mathrm{V}_{x_i}\left(\mathrm{E}_{\mathbf{x}_{\sim i}}\left(y \mid x_i\right)\right)}{\mathrm{V}\left(y\right)}$$

First order sensitivity index

Unconditional variance



Smoothed curve

$$\mathrm{E}_{\mathbf{x}_{\sim i}}\left(y \mid x_i\right)$$

First order sensitivity index:

$$\frac{\mathrm{V}_{x_i}\left(\mathrm{E}_{\mathbf{x}_{\sim i}}\left(y \mid x_i\right)\right)}{\mathrm{V}\left(y\right)}$$

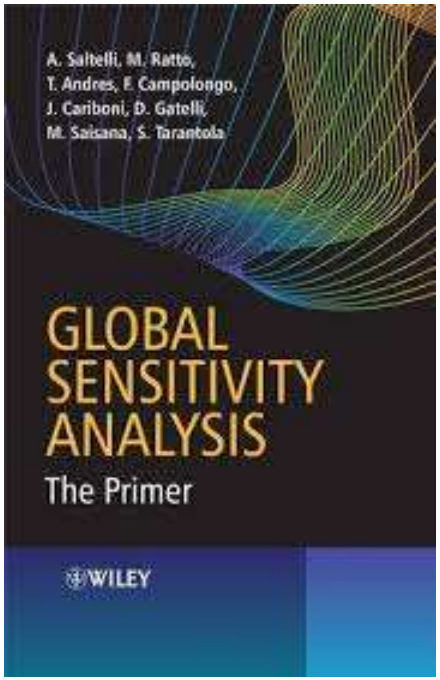
$$V_{X_i}\left(E_{\mathbf{X}_{\sim i}}\left(Y|X_i\right)\right)$$

First order effect, or top marginal variance=

= the expected reduction in variance than would be achieved if factor Xi could be fixed.

Why? See

this book



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]

Verification, Validation, and Confirmation of Numerical Models in the Earth Sciences, Naomi Oreskes, Kristin Shrader-Frechette, Kenneth Belitz, Science, New Series, Vol. 263, No. 5147 (Feb. 4, 1994), pp. 641-646.

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)

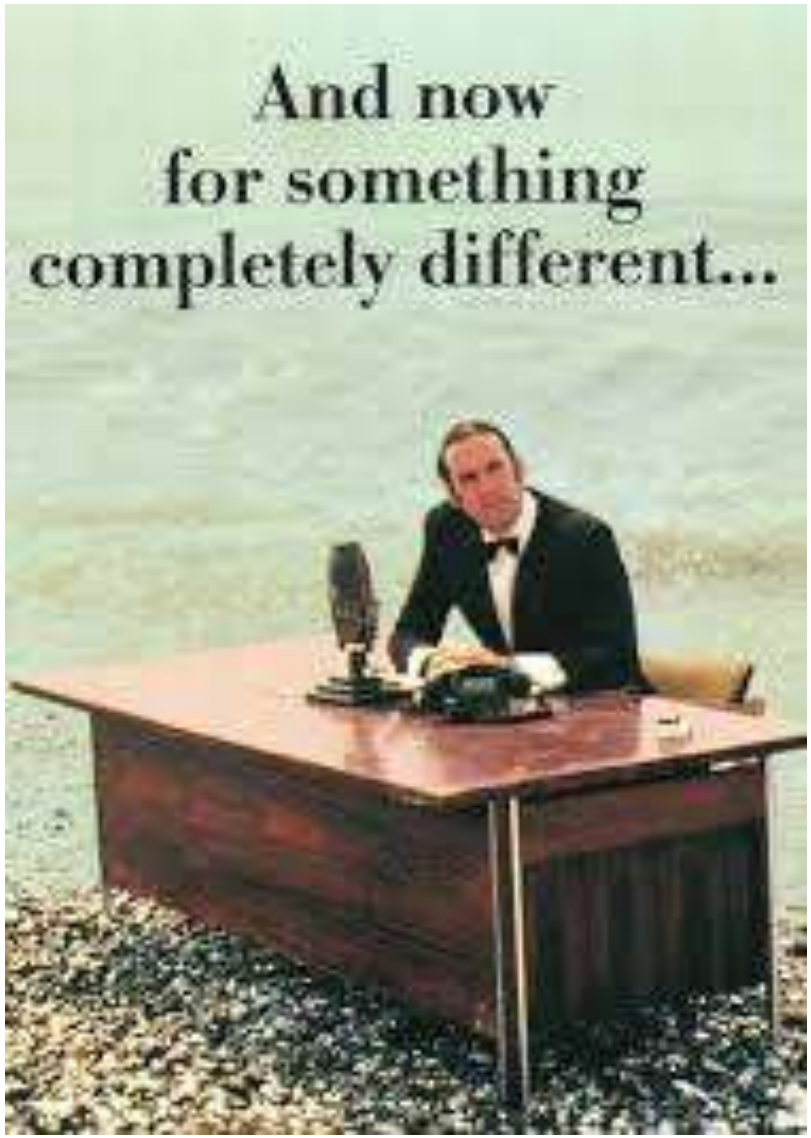
Personal note: I never run a
SA without finding more bugs

And of course please don't …

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

Discussion point

- Why should I not run a sensitivity analysis where each factors has a 5% uncertainty
- Why doing a sensitivity analysis if it can undermine an laborious quantification exercise?
- What do I do if this happens to be the case?



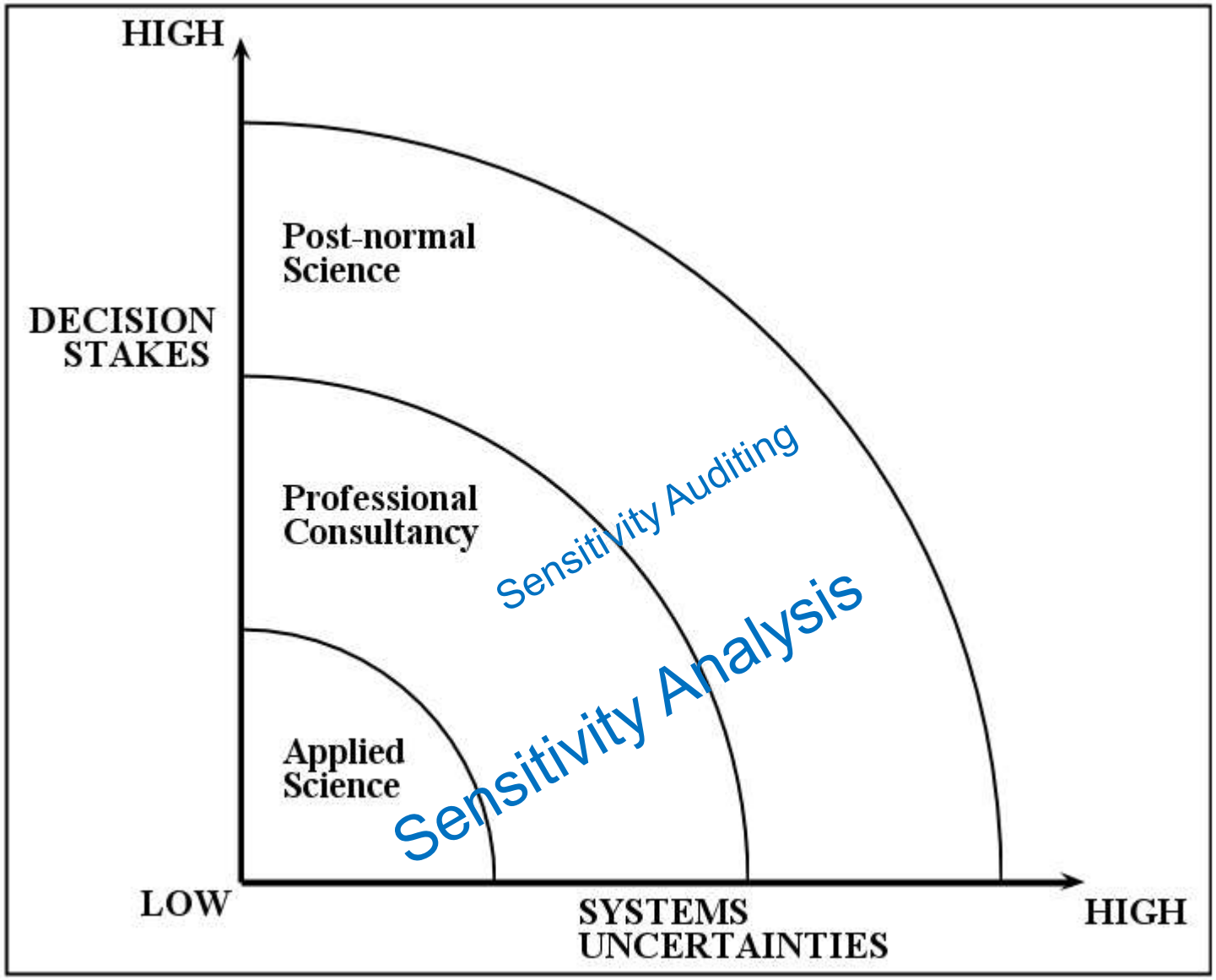
From sensitivity analysis to sensitivity auditing

Sensitivity auditing

- Originates from uncertainty & sensitivity analysis
- Addresses model-based evidence used for policy

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 science-policy interface, Issues in Science and Technology, Winter 2014, 79-85.
http://issues.org/30-2/andrea/


HIGH
DECISION STAKES
Post-normal Science
Professional Consultancy
Applied Science
Sensitivity Auditing
Sensitivity Analysis
LOW
SYSTEMS UNCERTAINTIES
HIGH

RULE ONE: Check against rhetorical use of mathematical modelling

The instrumental use of mathematical modelling to advance one's agenda

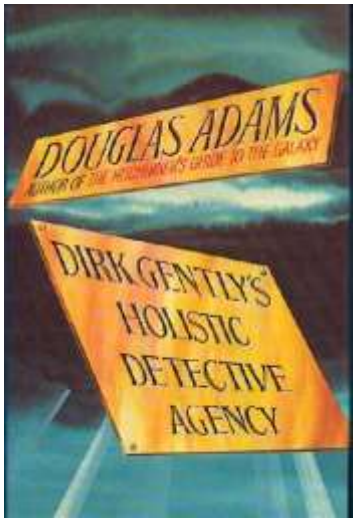
Rhetorical, or strategic

Like the use of Latin to obfuscate opponents.

RULE ONE: Check against rhetorical use of mathematical modelling

"Well, Gordon's great insight was to design a program which allowed you to specify in advance what decision you wished it to reach, and only then to give it all the facts. The program's task, […], was to construct a plausible series of logical-sounding steps to connect the premises with the conclusion."

Douglas Adam, 1987, Dirk Gently's holistic detective agency, p.69



About "All else being equal" (Caeteris paribus)

Models by their nature are like blinders. In leaving out certain things, they focus our attention on other things. They provide a frame through which we see the world.

Joseph E. Stiglitz, 2011, RETHINKING MACROECONOMICS: WHAT FAILED, AND HOW TO REPAIR IT, Journal of the European Economic Association August 2011 9(4):591–645

Caeteris are never paribus!

Philip Mirowski

"…To be fair, DSGE and similar macroeconomic models were first conceived as theorists' tools. But why, then, are they being relied on as the platform upon which so much practical policy advice is formulated? And what has caused them to become, and to stay, so firmly entrenched?"

The quote reported is from Miller, B., 2010, Opening Address, The Hearing Charter of the House Committee on Science and Technology and sworn testimony of economists Sidney Winter, Scott Page, Robert Solow, David Colander and V.V. Chari. See book on this slide.

RULE TWO: Adopt an 'assumption hunting' attitude;

What was 'assumed out'? What are the tacit, pre-analytic, possibly normative assumptions underlying the analysis?

Bogus Quantification: Uses and Abuses of Models

John Kay uncovers that the UK transport WebTAG model needs as input 'Annual Percentage Change in Car Occupancy up to 2036.'

John Kay, London School Economics, Columnist Financial Times

John Kay, Financial Times

Watch the videos from the workshop 'Significant digits. Responsible Use of Quantitative Information', Brussels, 11,9-10 June 2015.

https://ec.europa.eu/jrc/en/event/conference/use-quantitative-information

Philip Stark,
University of Berkeley

Contents lists available at ScienceDirect

Energy Policy

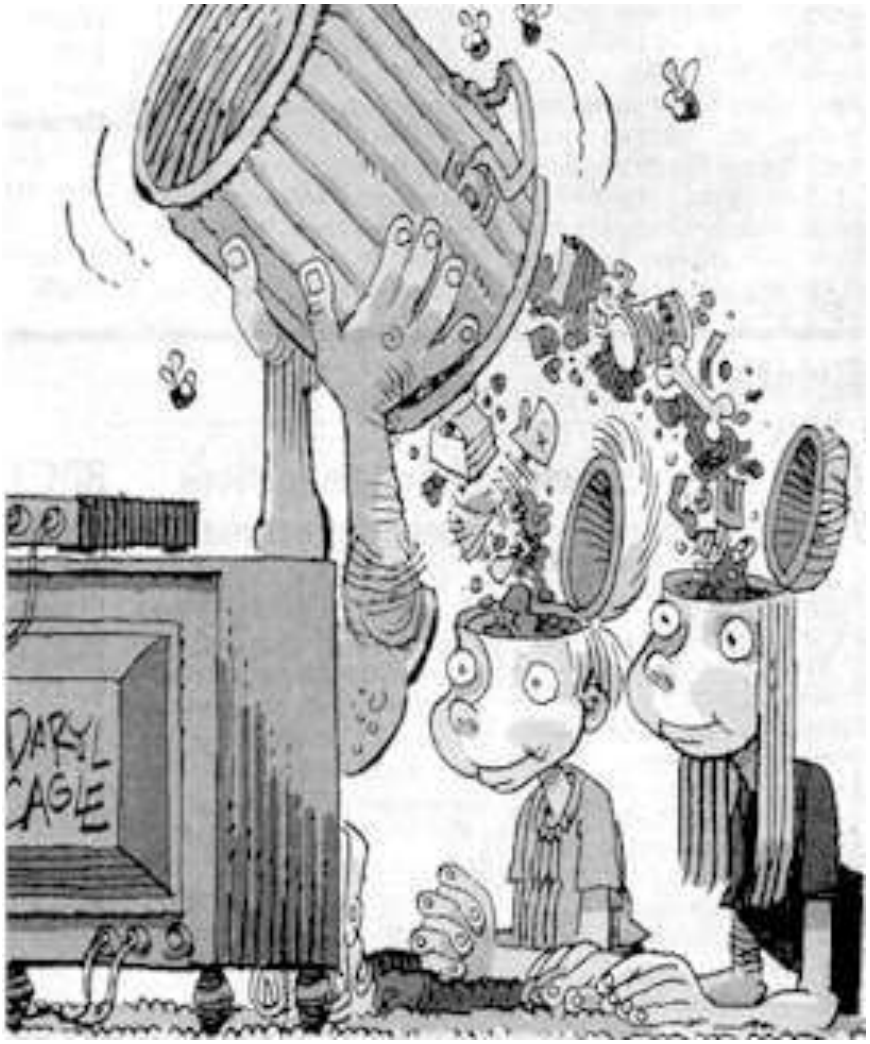
journal homepage: www.elsevier.com/locate/enpol

On the contribution of external cost calculations to energy system governance: The case of a potential large-scale nuclear accident

Erik Laes [a,*], Gaston Meskens [b], Jeroen P. van der Sluijs [c]

'[…] calculation of the external costs of a potential large-scale nuclear accident […] 'An [analysis] resulted in a list of 30 calculation steps and assumptions' …

RULE THREE: detect GIGO (Garbage In, Garbage Out)
Science or pseudo-science

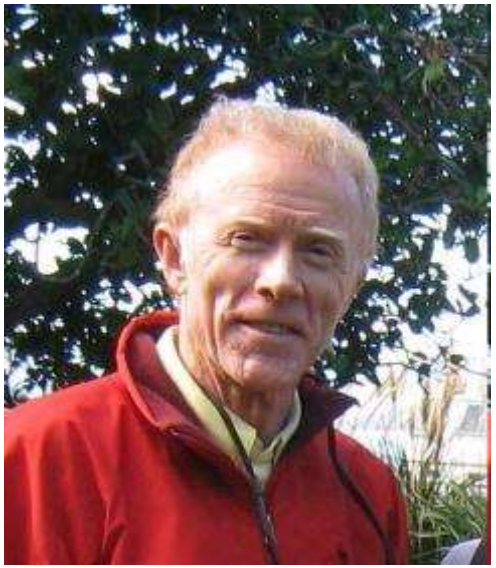


What is GIGO (Garbage In, Garbage Out) Science or pseudo-science "where uncertainties in inputs must be suppressed lest outputs become indeterminate"

From: Uncertainty and Quality in Science for Policy, by Silvio Funtowicz and Jerry Ravetz, Springer 1990.

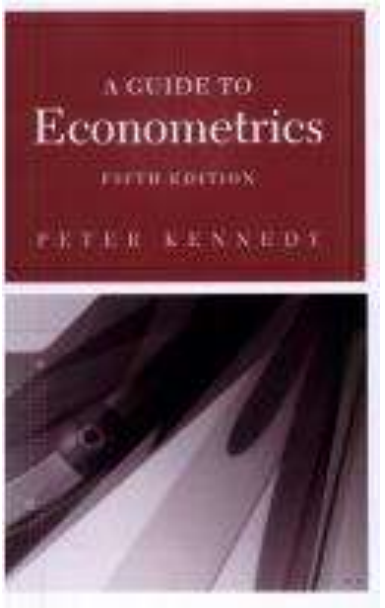
RULE FOUR: find sensitivities before sensitivities find you;

RULE FOUR: find sensitivities before sensitivities find you;



Peter Kennedy, A Guide to Econometrics.
Anticipating criticism by applying sensitivity analysis. This is one of the ten commandments of applied econometrics:

<<Thou shall confess in the presence of sensitivity.
Corollary: Thou shall anticipate criticism >>



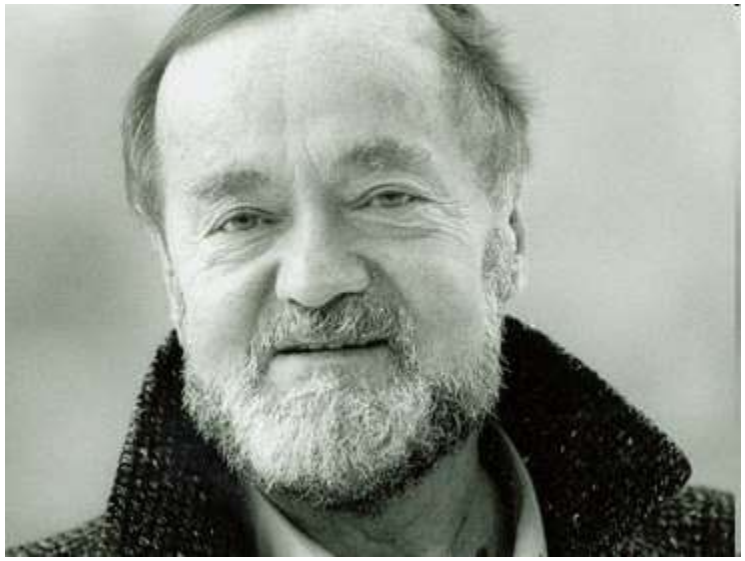
RULE FIVE: aim for transparency

[models should be made available to a third party so that it can] use the same data, computer model or statistical methods to replicate the analytic results reported in the original study.

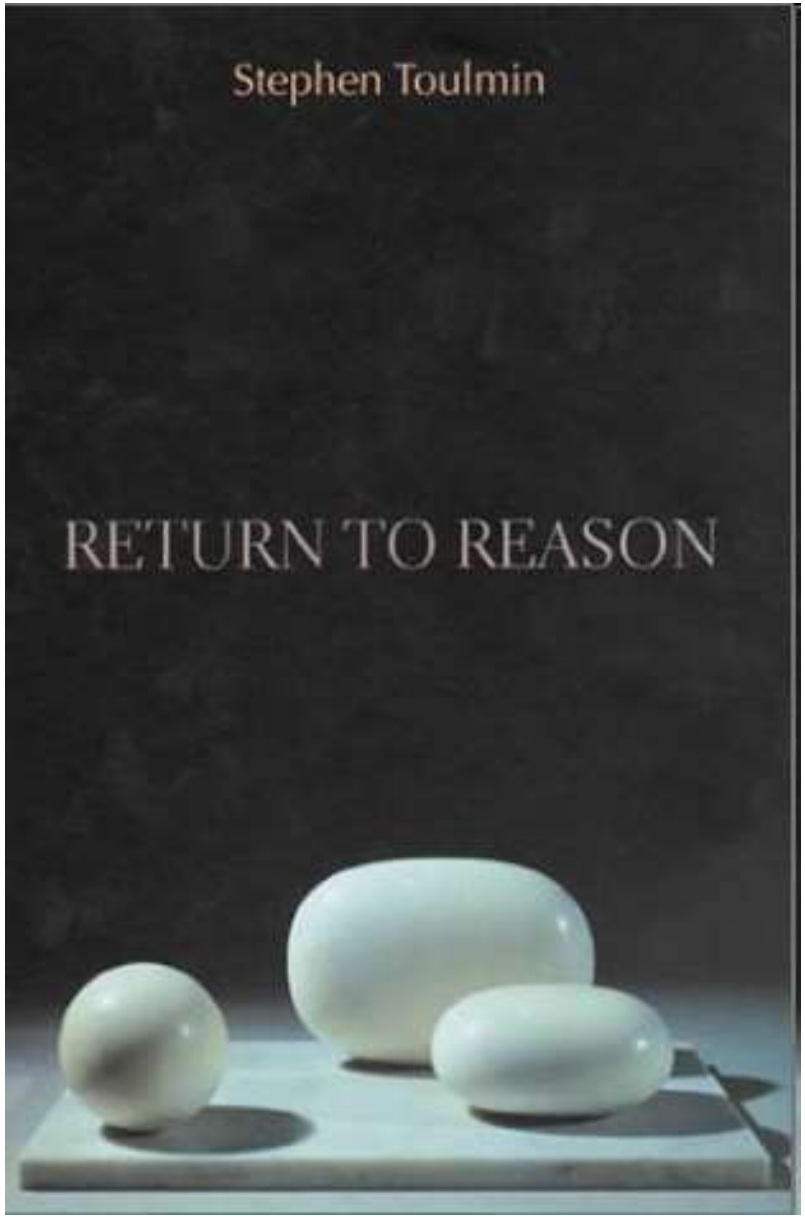
[…] The more important benefit of transparency is that the public will be able to assess how much an agency's analytic result hinges on the specific analytic choices made by the agency.

Friday, February 22, 2002
Graphic - Federal Register, Part IX
Office of Management and Budget
Guidelines for Ensuring and Maximizing the Quality, Objectivity, Utility, and Integrity of Information Disseminated by Federal Agencies; Notice; Republication
http://www.whitehouse.gov/omb/inforeg/

RULE SIX: Do the right sums



Do the sum right
Versus
Do the right sums
(Stephen Toulmin)
A plea for reasonableness versus rationality



RULE SIX: Do the right sums

Peter Kennedy's commandment of applied econometrics: 'Thou shall answer the right question', Kennedy 2007

Expertise and responsibility Rule 6

- Most analyses offered as input to policy are framed as cost benefit analysis or risk analyses.

Langdon Winner

Winner, L., 1986. The Whale and the Reactor: a Search for Limits in an Age of High Technology. The University of Chicago Press, 1989 edition.

RULE SEVEN: Explore diligently the space of the assumptions

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How to avoid a perfunctory sensitivity analysis

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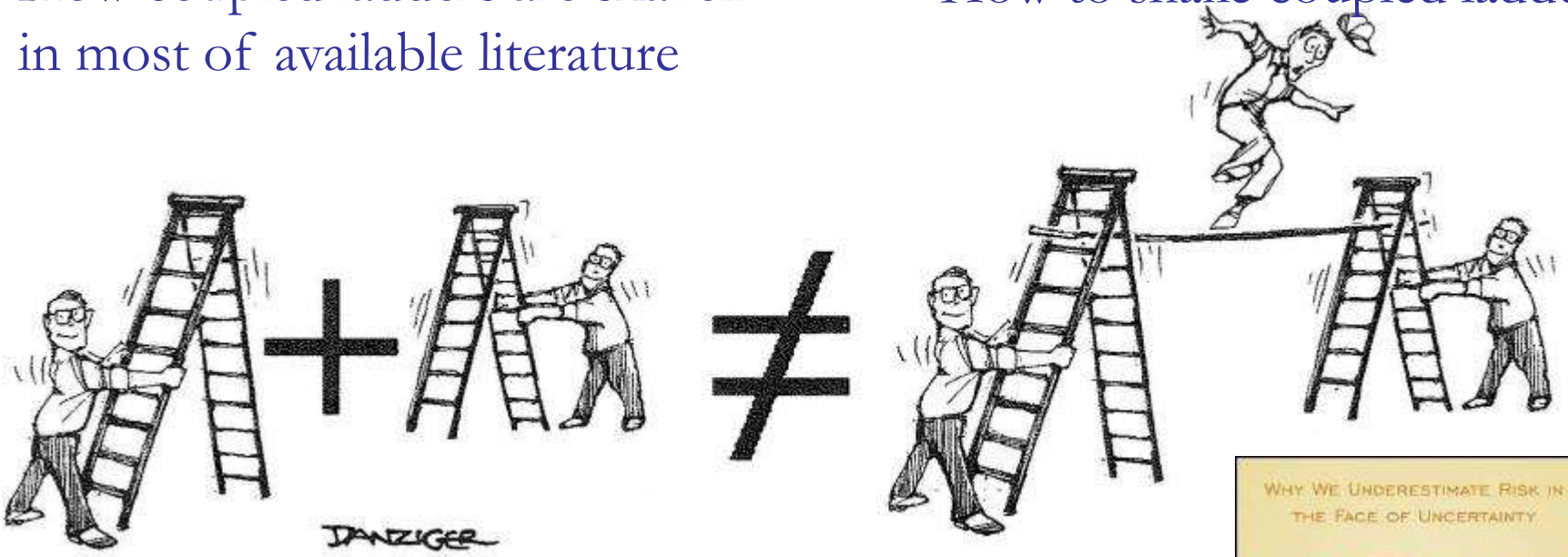
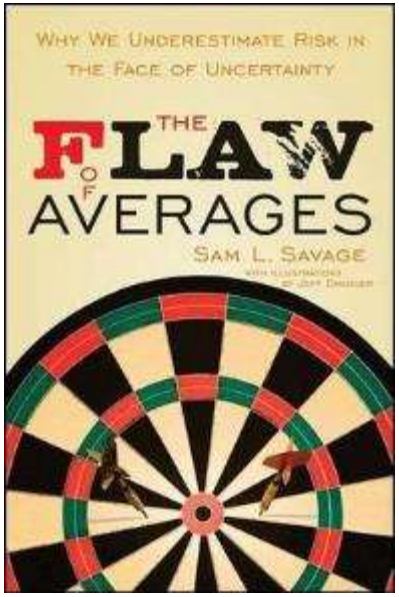
RULE SEVEN: Explore diligently the space of the assumptions

How coupled ladders are shaken in most of available literature

How to shake coupled ladders





Discussion points

- Can I recall an instance where uncertainties have been either amplified or deflated instrumentally?

Quantitative story-telling and responsible quantification

What is quantitative story telling?

- A truism: always listen more than one story
- An exhortation from philosophers
- A development from sensitivity analysis and sensitivity auditing
- A concept implicit in post-normal science's concept of "extended peer communities"

"There is only a perspective seeing, only a perspective "knowing"; and the more affects we allow to speak about one thing, the more eyes, different eyes, we can use to observe one thing, the more complete will our "concept" of this thing, our "objectivity", be."

Friedrich Nietzsche, Genealogy of Morals, Third Essay.

Stories, frames / framings, narratives

Some examples

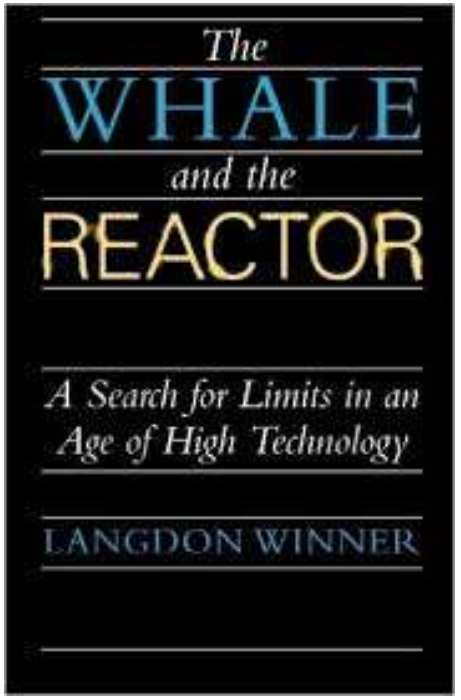
Frames

Most analyses offered as input to policy are framed as cost benefit analysis or risk analyses.

Langdon Winner

8

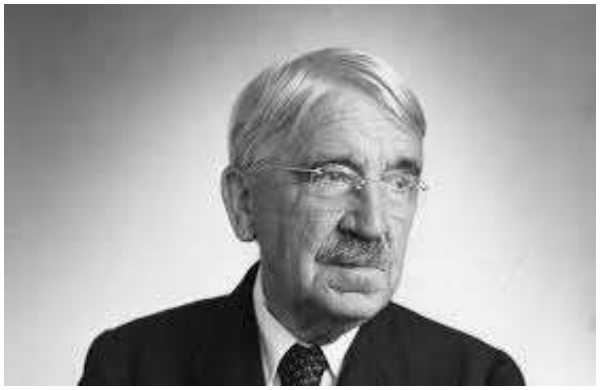
ON NOT HITTING THE TAR-BABY



Winner, L., 1986. The Whale and the Reactor: a Search for Limits in an Age of High Technology. The University of Chicago Press, 1989 edition.

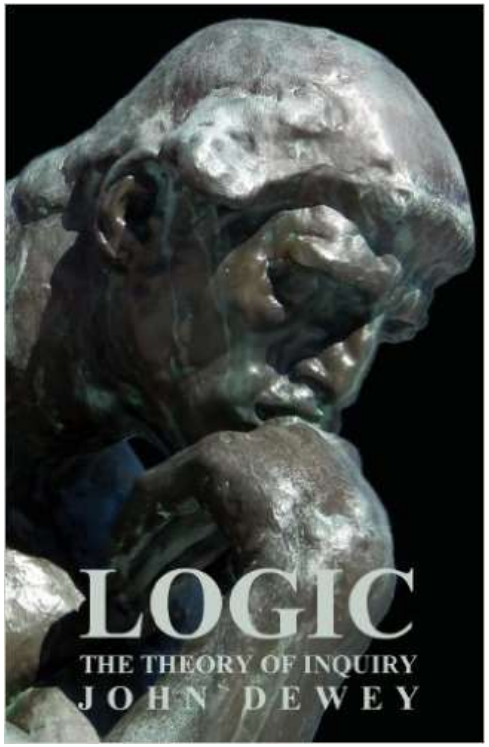
Frames

John Dewey suggested the concept of 'occupational psychosis'



John Dewey
1859-1952

- Thus CBA = professional psychosis of economists
- Funtowicz and Ravetz's Extended Peer Community because experts have 'lenses'
- Feyerabend's intuition that citizens mature by learning about experts' fallibility …

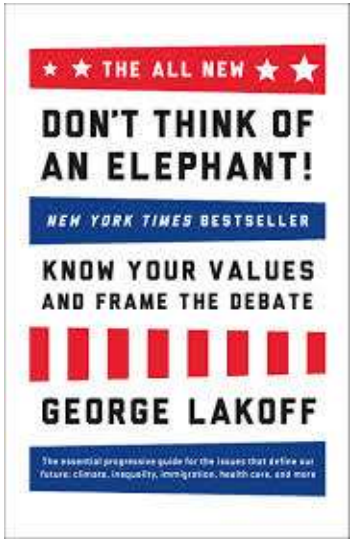


John Dewey, Logic: The Theory of Inquiry (1938), Saerchinger Press (2007)

Frames

The expression ‘tax relief’ is apparently innocuous but it suggests that tax is a burden, as opposed to what pays for road, hospitals, education and other infrastructures of modern life (Lakoff, 2004).

George Lakoff



Lakoff, G., 2010, Why it Matters How We Frame the Environment, Environmental Communication: A Journal of Nature and Culture, 4:1, 70-81.

Lakoff, G., 2004-2014, Don’t think of an elephant: know your values and frame the debate, Chelsea Green Publishing.

Frames

Published road accident statistics record the conditions of the driver as to alcohol or drug use but not the make and year of the car or its safety features (Gusfield, 1981).

Gusfield, J. (1981). The Culture of Public Problems. Drinking-Driving and the Symbolic Order. The University of Chicago Press.

Frames

"[…] genetically modified crops, declared safe by the scientific establishment, but reviled as Frankenfoods by the Subarus-and-sandals set", …(The Economist, 2014).

The Economist, Vermont v science, The little state that could kneecap the biotech industry, May 10th 2014

The New York Review of Books

Why Free Markets Make Fools of Us

Cass R. Sunstein

OCTOBER 22, 2015 ISSUE

Phishing for Phools: The Economics of Manipulation and Deception
by George A. Akerlof and Robert J. Shiller
Princeton University Press, 272 pp., $24.95

An advertisement for Rolls-Royce from the late 1950s

Frames

For Akerlof and Shiller - against what the 'invisible hand' would contend - economic actors have no choice but to exploit frames to 'phish' people into practices which benefit the actors not the subject phished.

George Akerlof

Robert R. Shiller

Frames as hypocognition & Socially constructed ignorance

For Rayner (2012) “Sense-making is possible only through processes of exclusion. Storytelling is possible only because of the mass of detail that we leave out. Knowledge is possible only through the systematic ‘social construction of ignorance’ (Ravetz, 1986)”

Steve Rayner

Jerry Ravetz

Ravetz, J., R., 1987, Usable Knowledge, Usable Ignorance, Incomplete Science with Policy Implications, Knowledge: Creation, Diffusion, Utilization, 9(1), 87-116.

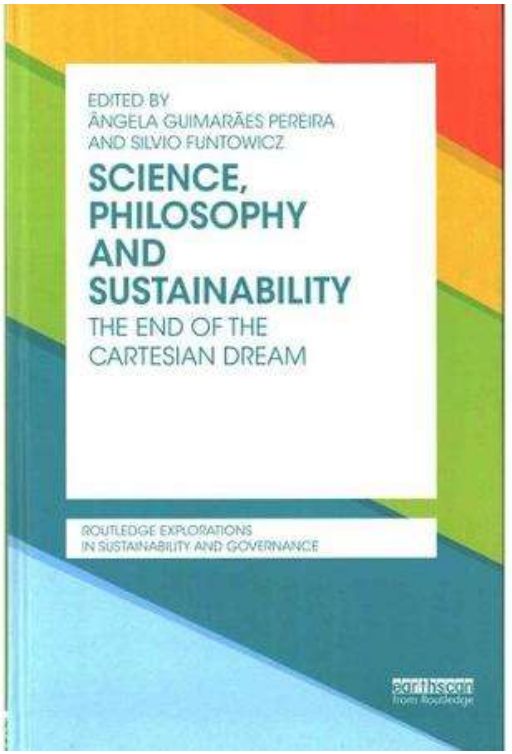
Rayner, S., 2012, Uncomfortable knowledge: the social construction of ignorance in science and environmental policy discourses, Economy and Society, 41:1, 107-125.

Rayner's (2012) strategies societies may use to deal with "uncomfortable knowledge".

- Denial: "There isn't a problem"
- Dismissal: "It's a minor problem"
- Diversion: "Yes I am working on it" (In fact I am working on something that is only apparently related to the problem)
- Displacement: "Yes and the model we have developed tells us that real progress is being achieved" (The focus in now the model not the problem).

Rayner, S., 2012, Uncomfortable knowledge: the social construction of ignorance in science and environmental policy discourses, Economy and Society, 41:1, 107-125.

- A plea for a rediscovery of ignorance – especially ignorance generated by science itself;

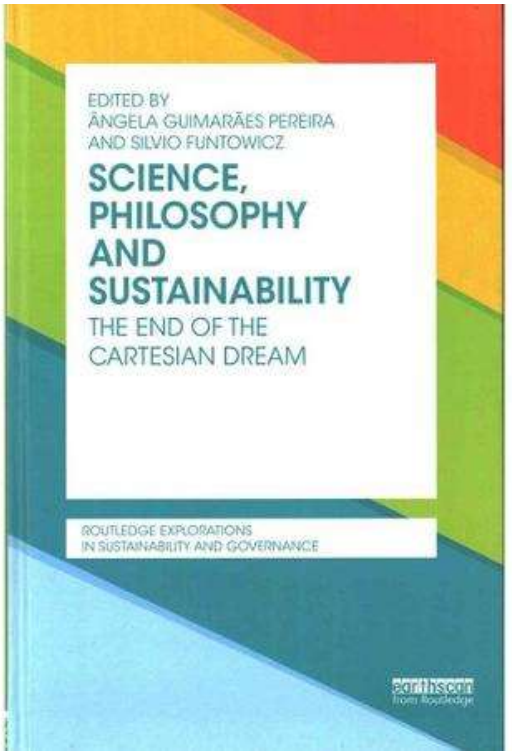


Ravetz, J., R., 2015, Descartes and the rediscovery of ignorance, in Guimarães Pereira, Â., and Funtowicz, S., Eds., 2015, The end of the Cartesian dream, Routledge's series: Explorations in Sustainability and Governance.

Ravetz, J., R., 1987, Usable Knowledge, Usable Ignorance, Incomplete Science with Policy Implications, Knowledge: Creation, Diffusion, Utilization, 9(1), 87-116.

- Dichotomy between knowledge and ignorance as problematic as that between facts and value;

- Ignorance useful: work can be done on its boundaries (finding where these can be penetrated, spotting signals of troubles ahead).



Ravetz, J., R., 2015, Descartes and the rediscovery of ignorance, in Guimarães Pereira, Â., and Funtowicz, S., Eds., 2015, The end of the Cartesian dream, Routledge's series: Explorations in Sustainability and Governance.

Ravetz, J., R., 1987, Usable Knowledge, Usable Ignorance, Incomplete Science with Policy Implications, Knowledge: Creation, Diffusion, Utilization, 9(1), 87-116.

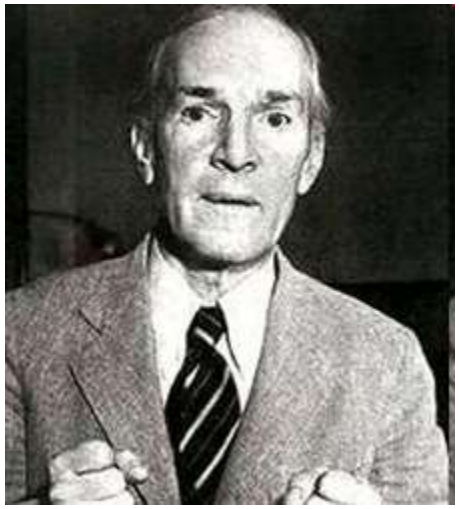
“Uncomfortable knowledge” can be used as a gauge of an institution’s health.

The larger the “uncomfortable knowledge” an institution needs to maintain, the closer it is to its ancient régime stage (Funtowicz and Ravetz, 1994).

Funtowicz, S.O. and Jerome R. Ravetz, 1994, Emergent complex systems, Futures, 26(6), 568-582.

Why frames ‘stick’

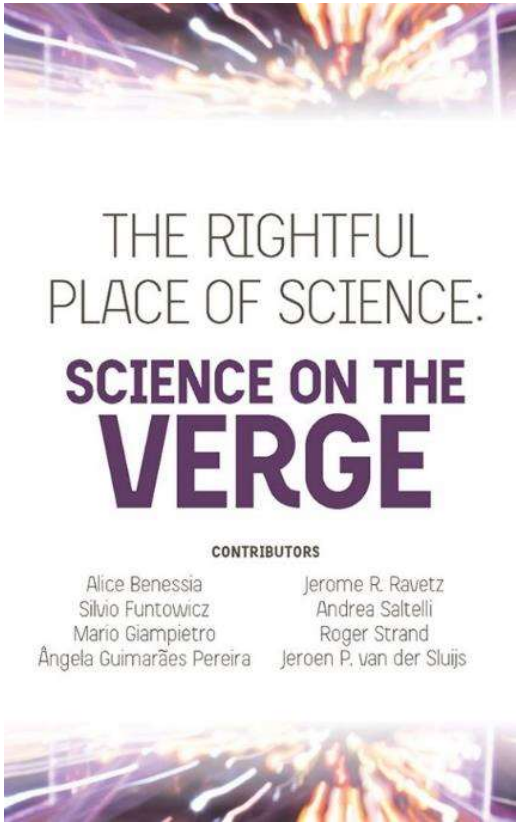
“If is difficult to get a man to understand something when his salary depends upon his not understanding it.”



Upton Sinclair

So what does quantitative story telling propose?

Instead of detailed quantification on a single[/few] frame[s] a rough quantitative appraise of a richer set of frames.



Andrea Saltelli and Mario Giampietro, The Fallacy of Evidence-Based Policy, in Benessia et al, 2016

Instead of Evidence-based policy: robust policy.

Test for:

- feasibility (compatibility with processes outside human control);
- viability (compatibility with processes under human control, in relation to both the economic and technical dimensions); and
- desirability (compatibility with a multitude of normative considerations relevant to a plurality of actors).

Andrea Saltelli and Mario Giampietro, The Fallacy of Evidence-Based Policy, in Benessia et al, 2016
Saltelli, A., Giampietro, M., Ravetz, J.R., 2016, Decalogue of the diligent quantifier. A Pledge, http://www.andreasaltelli.eu/file/repository/Decalogue_of_the_diligent_quantifier_online_Version_2.pdf

Techno-science is at the heart of contemporary narratives supporting ways to:

- innovate our way out of the economic crisis;
- overcome our planetary boundaries;
- achieve a dematerialized / circular / decarbonized economy;

Quantitative story telling will be used in the project Magic-Nexus to test the quality of these and others narratives.

MAGIC
NEXUS

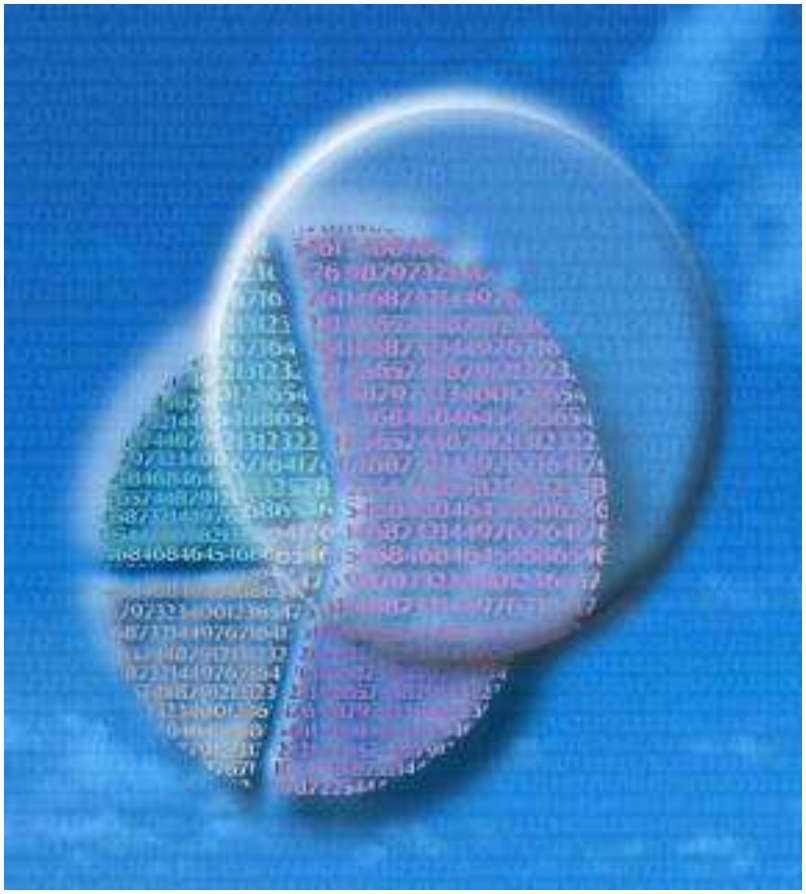
Saltelli, A., Giampietro, M., Ravetz, J.R., 2016, Decalogue of the diligent quantifier. A Pledge.

Excerpts:

Don't quantify at gun point

My license to quantify is also a license not to quantify

Mind frames; mind motivations and power relations



END

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