



Sensitivity analysis, sensitivity auditing and ethics of quantification

Andrea Saltelli Talk at the University of Reading, February 4th 2022, CREDS research consortium event https://www.creds.ac.uk/

Where to find this talk: www.andreasaltelli.eu



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(1)

CAETERIS ARE NEVER PARIBUS



🔁 andrea saltelli Retweeted

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



Sep 7, 2020

@Andrea saltelli

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

Embed

View on Twitter



Something general about mathematical modelling

Modelling is a craft more than a science

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



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

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





Robert Rosen

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



Naomi Oreskes

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

Models are not physical laws



Oreskes, N., 2000, Why predict? Historical perspectives on prediction in Earth Science, in Prediction, Science, Decision Making and the future of Nature, Sarewitz et al., Eds., Island Press, Washington DC "[…] to be of value in theory testing, the predictions involved must be capable of refuting the theory that generated them" (N. Oreskes)



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

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

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

E. Millgram The Great Endarkenment, p. 29

Caeteris are never paribus

Ceteris paribus or caeteris paribus is a Latin phrase meaning "all other things being equal" or "other things held constant" or "all else unchanged" (Wikipedia) The case of DSGE, dynamic stochastic general equilibrium models

Rational expectations of agents Efficient market hypothesis





Philip Mirowski

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

The US senate and Queen Elisabeth perplexed…







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

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

Why Sensitivity analysis?

It is in the guidelines!

EC impact assessment guidelines: sensitivity analysis & auditing



Better Regulation

European Commission. November 2021. "Better Regulation: Guidelines and Toolbox." https://ec.europa.eu/info/law/law-makingprocess/planning-and-proposing-law/betterregulation-why-and-how/better-regulationguidelines-and-toolbox_en

TOOL #65. UNCERTAINTY AND SENSITIVITY ANALYSIS

1. MAIN FEATURES

How

Uncertainty analysis aims at quantifying uncertainties in model results provided to the decision-makers due to uncertain assumptions/inputs. Sensitivity analysis allows identifying the uncertain assumptions mostly responsible for uncertainty in model results.

A transparent and high-quality impact assessment should acknowledge and, to the extent relevant or possible, attempt to quantify the uncertainty in results as it could change the ranking and conclusions about the policy options.

Assessing the uncertainties in model results by propagating model input uncertainties through the model, and **inferring** a posteriori the relevant uncertain inputs by subsequent statistical analysis.





Sensitivity analysis, page 562-563

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



Sensitivity auditing, page 563

It should be noted that sensitivity analysis addresses uncertainties that can be quantified (Box 3). In some cases, i.e. when a deeper assessment of the framing of the analysis is needed, or where there is a major disagreement among stakeholders about the nature of the problem, the analysis can be extended to **sensitivity auditing**.



COMMENT • 24 JUNE 2020



Five ways to ensure that models serve society: a manifesto

Pandemic politics highlight how predictions need to be transparent and humble to invite insight, not blame.

Andrea Saltelli , Gabriele Bammer, Isabelle Bruno, Erica Charters, Monica Di Fiore, Emmanuel Didier, Wendy Nelson Espeland, John Kay, Samuele Lo Piano, Deborah Mayo, Roger Pielke Jr, Tommaso Portaluri, Theodore M. Porter, Arnald Puy, Ismael Rafols, Jerome R. Ravetz, Erik Reinert, Daniel Sarewitz, Philip B. Stark, Andrew Stirling, Jeroen van der Sluijs & Paolo Vineis



Mind the assumptions

Assess uncertainty and sensitivity



Mind the hubris

Complexity can be the enemy of relevance

Mind the framing

Match purpose and context



Mind the consequences

Quantification can backfire.

Mind the unknowns

Acknowledge ignorance

Mind the assumptions

Assess uncertainty and sensitivity



Modelling without sensitivity analysis is like orthopedic without X-rays



An engineer's vision of UA, SA



One can sample more than just factors:

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

Assumption	Alternatives
Number of indicators	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





Each column is a sample from the distribution of a factor Each row is a sample trial to generate a value of *y*



Examples of distributions of input factors



How to generate the random sample?

Quasi random sequences

Ilya M. Sobol'





Sobol' sequences of quasirandom points



X1,X2 plane, 10000 Sobol' points

X1,X2 plane, 10000 random points

Sobol' sequences of quasi-random points against random points

Why quasi-random: they have faster convergence



Sergei Kucherenko, Imperial College London

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



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

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

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

Root mean square error over K=50 different trials.



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

Comparing three different sampling methods over an array of functions of different dimensionality and difficulty

The concept of effective dimension

the

Search...

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Discrepancy in 5, 10, 40 dimensions (model independent), op. cit. arXiv:1505.02350 Don't use plain LHS and think twice about optimized LHS

If in doubt try it for yourself with a set of test functions of varying dimensionality





Journal of COMPLEXITY

Journal of Complexity 19 (2003) 101-124

http://www.elsevier.com/locate/jco

The effective dimension and quasi-Monte Carlo integration $\stackrel{\mbox{\tiny\size}}{\approx}$

Xiaoqun Wang^{a,b,*} and Kai-Tai Fang^c

^a Department of Mathematical Sciences, Tsinghua University, Beijing 100084, China ^b School of Mathematics, University of New South Wales, Sydney 2052, Australia ^c Department of Mathematics, Hong Kong Baptist University, Hong Kong, China

Received 12 February 2002; accepted 6 November 2002

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?

Interaction?

$f = f_0 + \sum f_i + \sum \sum f_{ij} + \dots + f_{12\dots k}$ i i j>i $V(Y) = \sum V_i + \sum \sum V_{ij} + \ldots + V_{12\ldots k}$ \overline{i} i i > i

Why Sensitivity analysis?

It can answer interesting questions

Global Environmental Change 20 (2010) 298-302



Sensitivity analysis didn't help. A practitioner's critique of the Stern review Andrea Saltelli*, Beatrice D'Hombres

Joint Research Centre, Institute for the Protection and Security of the Citizen, Ispra, Italy

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



Nicholas Stern, London School of Economics

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

William Nordhaus, University of Yale Nobel 'Economics' 2018

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

How was it done? A reverse engineering of the analysis

Missing points



% loss in GDP per capita

Conclusion:

Model prediction are too uncertain to adjudicate the dispute about the urgency of action on climate change;

Both assertion (Stern) and refutation (Nordhaus) are indefensible

Sensitivity analysis here (by reverse engineering)



OPINION PETER COY

"social cost of carbon:

'The Most Important Number You've Never Heard Of'

Sept. 17, 2021



=\$56 a ton on average at a 3 percent discount rate

=\$171 a ton on average at a 2 percent discount rate"

The New York Times

Illustration by Arsh Raziuddin, The New York Times



The Social Cost of Carbon: Advances in Long-Term Probabilistic Projections of Population, GDP, Emissions, and Discount Rates

Kevin Rennert, Brian C. Prest, William A. Pizer, Richard G. Newell, David Anthoff, Cora Kingdon, Lisa Rennels, Roger Cooke, Adrian E. Raftery, Hana Ševčíková, and Frank Errickson

Working Paper 21-28 October 2021

Averaged till year 2300

Feeds into policy design

Why sensitivity analysis?

It allows interesting discoveries

Journal of the Royal Statistical Society





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

Ratings and rankings: voodoo or science?

Paolo Paruolo

University of Insubria, Varese, Italy

and Michaela Saisana and Andrea Saltelli European Commission, Ispra, Italy



University rankings such as ARWU and THES are volatile and technically unsound Journal of the Royal Statistical Society



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

Ratings and rankings: voodoo or science?

Paolo Paruolo University of Insubria, Varese, Italy

and Michaela Saisana and Andrea Saltelli European Commission, Ispra, Italy





2008 ARWU Alumni winning Nobel Prize Staff winning Nobel Prize Highly cited researchers Articles in Nature and Science Articles in Science and Social Sciences Citation Index Academic performance (size adjusted) 2008 THES Academic review Recruiter review Teacher/student ratio Citations per faculty International staff International students At times a model routinely used to produce point estimates becomes non conservative if the uncertainty is plugged in

Geophysical Research Letters

Research Letter 🔂 Open Access 💿 🛈

Current Models Underestimate Future Irrigated Areas



Limits of sensitivity analysis



Orrin H.

Pilkey

useless arithmetic

Cash's Predict the Futur

By Emironmental Scientists

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

Once H. Pilley & Linda Pilley-Janci

The map is not the territory

Useless arithmetic Wy Indexedul Sciences Carl Productive Focus Orme 11, Pillery & Lable Pillery-Java <>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 \rightarrow one is the low permeability of the geological formation \rightarrow 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 ³⁶Cl story) Type III error in sensitivity: Examples:

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

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



"Scientific mathematical modelling should involve constant efforts to falsify the model"

→ Organized skepticism (as per CUDOS)

Where to study sensitivity analysis?

A. Saltelli, M. Ratto, T. Andres, F. Campolongo, J. Cariboni, D. Gatelli, M. Saisana, S. Tarantola	
GLOBAL SENSITIVIT ANALYSIS The Primer	
⊛ ₩ILEY	

全局敏感性分析 【意】萨特利(A. Sahutti)等一著 坚麻斑 丁义明 琦 鸣 液结风口静 WILEY



Available for free at

http://www.andreasaltelli.eu

How is it done in practice?



Plotting the output as a function of two different input factors

Which factor is more important?





~1,000 blue points

Divide them in 20 bins of ~ 50 points

Compute the bin's average (pink dots)



Each pink point is ~
$$E_{\mathbf{X}_{i}}(Y|X_{i})$$



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

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





Which factor has the highest $V_{X_i}\left(E_{\mathbf{X}_{\sim i}}\left(Y|X_i\right)\right)$?
For <u>additive</u> models one can decompose the total variance as a sum of those partial variances

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

··· which is also how additive models are defined

Non additive models





Is this factor non-important?



For non-additive models use total sensitivity indices, whose theory is in the primer



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

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



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

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

Read chapter 1 and do the exercises

Why not using correlationregression based techniques? PCC, PRCC, SRC, SRRC

Reliability Engineering and System Safety 28 (1990) 229-253

Non-parametric Statistics in Sensitivity Analysis for Model Output: A Comparison of Selected Techniques

A. Saltelli

Commission of the European Communities, Joint Research Centre-Ispra Establishment, 21020 Ispra (Varese), Italy

&

J. Marivoet

Belgian Nuclear Research Establishment SCK/CEN, Boeretang 200, B-2400, Belgium

(Received 26 May 1989; accepted 3 August 1989)

Computational "tatistics & Data Analysis 13 (1992) 73-94 North-Holland

Sensitivity analysis for model output

Performance of black box techniques on three international benchmark exercises

A. Saltelli

Commission of the European Communities, Joint Research Centre, Ispra, Italy

T. Homma

Japan Atomic Energy Research Institute, Tokai Research Establishment, Department of Environmenial Safety Research, Tokai-Mura, Ibaraki, Japan

Received February 1990 Revised October 1990

They assume linearity (PCC) or monotonicity (PRCC), which is difficult to know *ex-ante* Secrets of sensitivity analysis

Why should one ever run a model just once? First secret: The most important question is the question.

Or: sensitivity analysis is not "run" on a model but on a model once applied to a question Second secret: Sensitivity analysis should not be used to hide assumptions [it often is]



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

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

Fourth (badly kept) secret:

There is always one more bug! =Lubarsky's Law of Cybernetic Entomology



Fifth secret: use SA to calibrate complexity



Model complexity



Model Complexity

Presented as 'Conjecture by O'Neill'

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



Lofti Aliasker Zadeh

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

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

SA can help to find this minimum



Model Complexity



Comment Open Access Published: 27 August 2019

A short comment on statistical versus mathematical modelling



Sixth secret:

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

Proving woldstay is one string the view of the series of the view of the series of the series And the series of t

Nassim Nicholas Taleb Author of the bestselling phenomenon The Black Swan Doing the right thing

or

Avoiding something wrong?

And of course please don't run a sensitivity analysis where each factors has a 5% (or 20%) uncertainty





Why?

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



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

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



Contents lists available at ScienceDirect

Environmental Modelling & Software

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

How to avoid a perfunctory sensitivity analysis

Andrea Saltelli*, Paola Annoni

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



OAT in 2 dimensions



Area circle / area square =?

~ 3/4

OAT in 3 dimensions



Volume sphere / volume cube =?

~ 1/2

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





How would you test the scaffolding?

How coupled ladders are shaken in most of available literature How to shake coupled ladders





Lessons from sensitivity analysis

• Global SA

• Memento

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



Model Complexity



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} 은 쩓, Ksenia Aleksankina ^c, William Becker ^d, Pamela Fennell ^e, Federico Ferretti ^d, Niels Holst ^f, Sushan Li ^g, Qiongli Wu ^h



5. Discussion

5.1. Reasons for bad practice


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

Why? → 3. Mathematical modelling is not a discipline

Based on a survey of modellers: "there is no dominating paradigm in modelling and simulation… simulation verification is mostly a trial and error activity → challenges model/simulation validity"

Padilla, J. J., Diallo, S. Y., Lynch, C. J., & Gore, R. (2018). Observations on the practice and profession of modeling and simulation: A survey approach. SIMULATION, 94(6), 493–506.

··· mathematical modelling cannot do this:



EWS AMERICAN STATISTICAL ASSOCIATION Promoting the Practice and Profession of Statistics

732 North Washington Street, Alexandria, VA 22314 + (703) 684-1221 + Toll Free: (888) 231-3473 + www.amstat.org + www.twitter.com/AmstatNews

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

Provides Principles to Improve the Conduct and Interpretation of Quantitative Science March 7, 2016

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

Why? → 4. Good practices require training in statistics

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

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

nature communications

Comment Open Access Published: 27 August 2019

A short comment on statistical versus mathematical modelling

Andrea Saltelli 🖂

Nature Communications 10, Article number: 3870 (2019)Cite this article37k Accesses31 Citations416 AltmetricMetrics

While the crisis of statistics has made it to the headlines, that of mathematical modelling hasn't. Something can be learned comparing the two, and looking at other instances of production of numbers. Sociology of quantification and post-normal science can help.

Sociology of quantification? Post normal science? → sensitivity auditing and ethics of quantification

"Sensitivity auditing is a wider consideration of the effect of all types of uncertainty, including structural assumptions embedded in the model, and subjective decisions taken in the framing of the problem."



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



"... and to

anticipate criticism by third parties. 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."



November 2021

Assess uncertainty and sensitivity

Mind the hubris

Complexity can be the enemy of relevance

Mind the framing

Match purpose and context



Mind the consequences

Quantification can backfire.

Mind the unknowns

Acknowledge ignorance

Assess uncertainty and sensitivity



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



Assess uncertainty and sensitivity



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Complexity can be the enemy of relevance



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

SUPPLEMENTARY INFORMATION

1. Additional information and references >260 references



Model complexity



O'Neil conjecture and effective dimension; CV=coefficient of variation= STD/mean; k model dimensionality

Interactions



Up to the k-th order Up to the n-th order with $n \le k$

From A. Puy et al, "Effective dimension and model uncertainty", **submitted**

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

SUPPLEMENTARY INFORMATION

1. Additional information and references >260 references

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





ELSEVIER

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

Ulrich Beck

(1944 - 2015)



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

Andrea Saltelli ^{a, b} $\stackrel{\circ}{\sim}$ $\stackrel{\boxtimes}{\sim}$, Lorenzo Benini ^c, Silvio Funtowicz ^a, Mario Giampietro ^{d, e}, Matthias Kaiser ^a, Erik Reinert^{a, f}, Jeroen P. van der Sluijs^{a, g, h}



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





Ulrich Beck (1944 –2015) The technique is never neutral. How methodological choices condition the generation of narratives for sustainability





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

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

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Quantification can backfire.

Mind the unknowns

Acknowledge ignorance

Mind the consequences

Quantification can backfire.



From the risk of financial products to the management of costal zones to the models for disaster insurance bad modelling may lead to wrong decisions

SUPPLEMENTARY INFORMATION

1. Additional information and references >260 references

PATHWAYS TO SUSTAINABILITY

THE POLITICS OF UNCERTAINTY

Challenges of Transformation



3

SHARING RISKS OR PROLIFERATING UNCERTAINTIES?

Insurance, disaster and development

Leigh Johnson

Model-based parametric insurance led to dramatic consequences for developing countries experiencing draughts

Open access: https://www.taylorfrancis.com/books/politicsuncertainty-ian-scoones-andystirling/e/10.4324/9781003023845

Assess uncertainty and sensitivity

Mind the hubris

Complexity can be the enemy of relevance

Mind the framing

Match purpose and context



Mind the consequences

Quantification can backfire.



Mind the unknowns

Acknowledge ignorance

Mind the unknowns

Acknowledge ignorance

"there is no number-answer to your question"





SUPPLEMENTARY INFORMATION

Anthony Fauci

1. Additional information and references >260 references

Andrea Saltelli

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Antonio Andreoni

Why ethics of our antification or Or UCL Institute for Innovation and Public Purpose; South African Research Chair in Industrial Development, University of Johannesburg, South

Wolfgang Drechsler

Tallinn University of Technology, Estonia; UCL Institute for Innovation and Public Purpose; Davis Center at Harvard University, United States

Jayati Ghosh

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Andy Stirling

Science Policy Research Unit, University of Sussex

Ting Xu

School of Law at the University of Essex



UCL Institute for Innovation and Public Purpose

WORKING PAPER WP 2021/05



 \cdots our world is structured by numbers, visible and invisible, where truth is conveyed and reality constructed

Numbers are seductive, performative, confer to their masters' epistemic power and legitimacy

Governing the modern state, or even contesting it, without numbers is impossible

Numbers are the prevalent means to express value in our societies … Access & production of numbers reflect and reinforce power imbalances



UCL Institute for Innovation and Public Purpose

WORKING PAPER WP 2021/05 Numbers capture our attention; they illuminate the part of reality which is being numerified, and fatally push those parts into the background which come without the clothing of …

 \cdots numbers are so deeply entrenched in our existence that we barely reflect on them critically them anymore — too close to us, they have become part of the very lens through which we attend to and comprehend the world.



Scope for harm from 'wrong numbers' e.g. in :

- Medical research
- Higher education
- Governance of science
- Finance
- Numbers from international organizations
 - Food and Agriculture Organization
 - The World Bank
 - OECD
 - ...

IIPP

'Trendy' methods may also harm

- Randomized control trials) may be misused to suggest more general conclusions that may not be valid
- Sophisticated statistical/econometric techniques that can be designed in ways that promote particular policy conclusions reflecting researchers' biases



HUMANITIES AND SOCIAL SCIENCES COMMUNICATIONS | (2020)7:69 | https://doi.org/10.1057/s41599-020-00557-0

Humanities & Social Sciences Communications



ARTICLE

https://doi.org/10.1057/s41599-020-00557-0

OPEN

From sociology of quantification to ethics of quantification

Andrea Saltelli[™] & Monica Di Fiore[™]

Give me a number!

Numbers, visible and invisible, pervade our life, dominate the language of our communication, and accelerate all our transactions. What price is being paid?


<u>Ethics of quantification, Video curated by the Open</u> <u>University of Catalonia, September 2011.</u>



http://materials.cv.uoc.edu/cdocent/PID_00284929/

The End

@andreasaltelli



 $= \frac{V_{X_i} \left(E_{\mathbf{X}_{\sim i}} \left(Y | X_i \right) \right)}{\sum_{i=1}^{n} \left(Y | X_i \right)}$ V(Y)

The partial variance divided by the total variance is the so-called sensitivity index of the first order, identical in formulation to Pearson's correlation ratio There are terms which capture two-way, three way, … interactions among variables.

All these terms are linked by a formula

Variance decomposition (ANOVA)

V(Y) =

 $\sum_{i} V_{i} + \sum_{i,j>i} V_{ij} + \dots + V_{123\dots k}$

Variance decomposition (ANOVA)

When the factors are independent the total variance can be decomposed into main effects and interaction effects up to the order k, the dimensionality of the problem.

If fact interactions terms are awkward to handle: **just** the **second** order terms for a model with k factors are as many as $k(k-1)/2 \cdots$

(10 factors=45 second order terms)

Wouldn't it be handy to have just a single 'importance' terms for all effects, inclusive of first order and interactions?

In fact such terms exist and can be computed easily, without knowledge of the individual interaction terms

Thus given a model $Y=f(X_1, X_2, X_3)$

Instead of $V=V_1+V_2+V_3+$ $+V_{12}+V_{12}+V_{23}+$ $+V_{12}+V_{12}+V_{23}+$ $+S_{12}+S_{13}+S_{23}+$

 $+ V_{12} + V_{13} + V_{23} + V_{123}$ $+ V_{123}$

 $+ S_{123}$

We have:

$$S_{T1} = S_1 + S_{12} + S_{13} + S_{123}$$

(and analogue formulae for S_{T2} , S_{T3}) which can be computed without knowing S_1 , S_{12} , S_{13} , S_{123}

 S_{T1} is called a total effect sensitivity index

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

Total effect, or bottom marginal variance=

= the expected variance that would be left if all factors but Xi could be fixed (self evident definition)

 $S_{Ti} \equiv \frac{E(V(Y|\mathbf{X}_{\sim i}))}{V_Y}$

Literature search in Scopus

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



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

subject areas >100 articles

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

 \rightarrow 324 articles, divided among authors

Cleansing manually irrelevant articles:

 \rightarrow 280 articles



Still many papers apply an OAT SA: 65%

What if the model is truly linear?

Linear Nonlinear Unclear

7% 61% 32%

Linear

Nonlinear Unclear

7% 61% 32%

65% highly cited articles are OAT

Taking all unclear = linear → still many papers wrong (OAT & non-linear model)